CIRCULAR

OF THE

Golden State

AND

Miners' Iron Works

Nos. 237 to 257 First Street,

SAN FRANCISCO, CAL.

1881:
B. DORE & CO., PRINTERS,
512 Sacramento Street,
SAN FRANCISCO.

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PREFACE.

The object of the proprietors of the Golden State and Miners' Iron Works in preparing the present circular has been to make it additional to an advertising medium of their various manufactures and extensive pattern list, a text book of reference which shall meet the requirements of the practical mechanic and miner as well as the mechanical, steam and hydraulic engineer.

By means of our new tables and rules, many of the more difficult and important problems in the various branches of engineering are answered direct, or solved with the utmost ease.

Due acknowledgments of indebtness are hereby made to the Manual of Rules, Data, etc., by D. H. Clark, C. E., for Table 1 on "The Properties of Saturated Steam;" to the Journal of Franklin Institute on Professor Hirn's Calorimeter; to the Treatise on Steam Engineering by John W. Nystrom, C. E., on the proper proportions of Grate Surface, Heating Surface and Chimneys of Boilers; and to the Quartz Operator's Hand Book, by P. M. Randall, C. E., on Assaying and Testing of Ores.

The Tables with respect to the Flow of Water Through Pipes and Open Channels, have been computed on the experimental data from the "Treatise of Water Supply Engineering," by J. T. Fanning, C. E.

Our aim, as hitherto, is to furnish our patrons with the best machinery for the purposes designed at the lowest rates. This, our long experience and improved facilities, will enable us to accomplish. Not only does this statement hold good with respect to successfully competing with home manufacturers, but in consideration of our ready accessibility to all the principal mining districts by means of the present systems of railroads radiating from San Francisco, it applies with especial force in regard to

those manufactures by parties not favored with those advantages and who are but partially conversant with the wants of the mining community.

California is justly credited with the honor of having accomplished more during the last thirty years toward perfecting quartz machinery than in the two thousand years preceding. The achievements of the proprietors of the Golden State and Miners' Iron Works in attaining this important result are well attested by the great amount of quartz machinery of their manufacture now working with the highest satisfaction to all concerned, in all the principal mining districts of the Pacific States and Territories, Mexico and Central and South America. Our motto is to keep fully up with the progress of the times, to thoroughly investigate any proposed improvement or invention, and to adopt the best for the benefit of our patrons.

We have no hesitancy in asserting that we can and will, furnish all kinds of Mining Machinery, better adapted to the required treatment of ores, than can be had from any other source, and at prices as low, if not lower, than a similar quality of machinery can be furnished from any part of the United States or from Europe.

Gratified that our efforts to excel in the line of our business are signally appreciated by all conversant with our manufactures, and grateful to them for past favors, we would most respectfully solicit from them, and the discriminating public, a continuance of that patronage in which we have hitherto so largely shared, assuring them of our utmost endeavors in the execution of their orders so as to give entire satisfaction, and to merit still farther their esteem and confidence.

Accurate plans, specifications and estimates will be furnished for every description of machinery on application.

SAN FRANCISCO, 1881.

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TABLES.

GOLDEN STATE

—AND—

MINERS' IRON WORKS.

CASTINGS.

IRON AND BRASS.

ARCHITECTURAL	SHIP
AGRICULTURAL	STEAM ENGINE
BOILER	STREET
GEAR	SIDE WALK
MINING	WORK SHOP
MILL (various)	ETC., ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

STEAM ENGINES.

COMPOUND	OSCILLATING
HIGH PRESSURE	PORTABLE
HORIZONTAL	PROPELLER
LOCOMOTIVE	SAW MILL
LOW PRESSURE	STATIONERY
MARINE	STEAM BOAT
ETC., ETC., ETC.	VERTICAL

Of the best material, best workmanship, and at the lowest rates.

STEAM ENGINE FITTINGS.

ANCHOR BOLTS	PACKING
CONDENSERS	" HEMP
COUPLINGS	" PATENT
EXHAUST-PIPES	" RUBBER
FEED PUMPS	REGISTERS
GOVERNORS	STEAM GAUGES
HEATERS	STEAM PIPES
INDICATORS	VALVES (Globe)
OILERS	WASHERS
OIL CUPS	ETC., ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

BOILERS.

CORNISH	PORTABLE
SECTIONAL	STATIONARY
HORIZONTAL	TUBULAR
FLUE	UPRIGHT
MARINE	ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

BOILER FITTINGS.

BLOW-OFF COCKS	MUD VALVES
BOILER STANDS	RETENTION VALVES
BREECHINGS	SAFETY VALVES
DOORS	SAFETY VALVE SCALES
DOOR LININGS	SAFETY VALVE WEIGHTS
FIRE FRONTS (Single)	SMOKE STACKS
FIRE FRONTS (Double)	STEAM GAUGES
FIRE BACKS	STEAM PIPES
FEED PIPES	STEAM WHISTLES
GRATE BARS	WATER GAUGE COCKS
GRATE RESTS	WATER VALVES
ETC., ETC.	ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

WATER WHEELS.

BREAST	JONVAL
CENTRAL DISCHARGE	OUTER DISCHARGE
FOURNERON	OVER-SHOT
HURDY-GURDY of all the Various Styles	PONCELET
	UNDERSHOT
ETC., ETC., ETC.	ETC., ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

MILLS.

BARK	QUARTZ
CHILIAN	" (Prospecting)
COFFEE, (Dressing)	RICE
COPPER	SAW
COTTON	" (Gang)
FLOUR	" (Single Circular)
GOLD	" (Double Circular)
GRIST	SILVER
MALT	SPICE
PAPER	SUGAR
POWDER	WOOLEN
ETC., ETC.	ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

MACHINES.

BOLTING	PLANING, (for iron)
BOLT-SAWING	PLANING, (for wood)
BLUBBER-CUTTING	PUNCHING
BROOM HANDLE SAW	SHEARING
DREDGING	SHINGLE
GUMMING	SHAPING
HAND SAWING	SMUT
LATH SAWING	STICKING
MORTICING	TENNONING
NOSING	TONGUING & GROOVING
ETC, ETC., ETC.	ETC., ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

PRESSES.

CLOTH
CIDER
COTTON
DROP
HAY
HYDRAULIC
MACCARONI
OIL
SCREW
SCUM
VERMICELLI
WOOL
WIRE
ETC., ETC., ETC.

Of the best materials, best workmanship and at the lowest rates.

PUMPS.

CORNISH
FORCE
FORCE AND LIFT
JACK HEAD
LIFT
SHIP'S
STEAM
ETC., ETC., ETC.

Of the best material, best workmanship and at the lowest rates.

FURNACES.

ASSAYERS
CALCINING
CHLORIDIZING
CUPOLA
PORTABLE
QUICKSILVER
REVERBERATORY
REVOLVING
ROASTING
SMELTING

Of the best material, best workmanship, and at the lowest rates.

QUARTZ MACHINERY.

AGITATORS
AMALGAM SAFES
AMALGAMATING PLATES
ARRASTRAS
CIRCULAR BUDDLES
CRUCIBLES
CRUSHING ROLLERS
CONCENTRATORS (dry)
" (wet)
CAMS (single armed)
CAMS (double armed)
GRINDERS
PROSPECTING BATTERIES OF TWO STAMPS
PESTLES
PAN DIES
QUARTZ MILL FRAMES (Iron)
" " " (Wood)
QUICKSILVER RIFFLES
RETORTS
RETORT STANDS
ROCK BREAKERS
REVOLVING BLANKETS
RUSSIA IRON SCREENS

QUARTZ MACHINERY.

GRINDERS & AMALGAMATORS
GUIDES
GERMAN BARRELS
INGOT MOLDS
LATCHES
MORTARS—HIGH
" —LOW
" —SECTION
" —HAND
MORTAR DIES
MULLERS
MULLER SHOES
SELF-FEEDERS
SEPARATORS OR SETTLERS
STAMP HEADS
STAMP SHOES
STAMP STEMS
SHAFTING
TAPPETS—GIB
" —COLEMAN
WIRE SCREENS
ETC., ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

SUGAR MILL MACHINERY.

AGITATORS
AIR PUMPS
BAY FILTERS
BLOW-UPS
BONE MILLS
CENTRIFUGAL DRYERS
CHARCOAL FILTERS
CANE & MASH CARRIERS
EVAPORATING PANS OR COPPER
ELEPHANTS
HEATERS
LIQUOR APPARATUS
POWER ROLLS, Animal
" " Steam
" " Water
PUMPS
REFINERS
SUGAR MOLDS
VACUUM PANS
ETC., ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

OIL MILL MACHINERY.

BLUNDELL'S PRESSES
CRUSHING ROLLS
EDGING STONES
HYDRAULIC PRESSES
ETC., ETC.
HEATING PANS
OIL PRESSES
PUMPS
REFINING KETTLES
ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

FLOUR MILL MACHINERY.

BAILS	IMPROVED MILL SPINDLES
BUSHES	MILL STONES
BOLTING MACHINES	PORTABLE GRIST MILL
CONVEYORS	PROOF STAVES
ELEVATORS	SEPARATORS
EXHAUST FANS	SILENT FEED
GEARING	SMUT MACHINES
HOISTING SCREWS	ETC., ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

SAW MILL, WOOD CUTTING & STONE MACHINERY.

ARBOR BOXES	IMPROVED HEAD BLOCKS
BAND SAWS	IMPROVED SELF ACTING
BELT FEED	FEED & BACKING MOTION
CARRIAGE MOUNTINGS	MARBLE SAWS
CARRIAGE ROLLS	MERRIMAN'S SAWS
CUT-OFF ARBORS	MULEY SAWS
CIRCULAR SAWS	RE-CUTTING SAWS
EDGING ARBORS	RUBBER BEDS
FRICTION FEED	SAW FRAMES
FRAME OR GATE SAWS	SLIDING ARBORS
GILCHRIST'S SAWS	SWEEP SASH SAWS
HAUL-UP GEAR	SWING CROSS-CUT SAWS
HAND CROSS-CUT SAWS	TURN OVER GEAR
IMPROVED GUIDES	ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

HOISTING MACHINERY.

CAPSTANS	STEAM ELEVATORS
DERRICK CRANES	SPUR GEAR HOISTS
FRICTION GEAR HOISTS	WINDLASSES
HYDRAULIC HOISTS	WHIMS
HYDRAULIC ELEVATORS	ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

HYDRAULIC MINING MACHINERY.

DISTRIBUTORS
HOSE PIPES
HYDRAULIC HOSE COVERING
HURDY-GURDY DERRICKS
ETC., ETC.
LITTLE GIANTS
MONITORS
NOZZLES
WATER PIPES

Of the best material, best workmanship, and at the lowest rates.

RETORTS, STILLS AND MOULDS.

GAS RETORTS
GOLD AMAL. RETORTS
GOLD INGOT MOULDS
PETROLEUM RETORTS
PETROLEUM STILLS
QUICKSILVER RETORTS
SILVER AMAL. RETORTS
SILVER INGOT MOULDS
SPIRIT STILLS
SULPHUR RETORTS ETC.

Of the best materials, best workmanship, and at the lowest rates.

SHIP CASTINGS AND SHIP WORK.

DECK GRATINGS
DECK PIPES
GYPSEYS
HAWSER BITTS
HAWSER PIPES
KEDGES
PUMPS
PUMP GEAR
RUDDER HEADS
WARPING CHOCKS
WINDLASSES
ETC., ETC., ETC.

Of the best material, best workmanship and at the lowest rates.

TOOLS.

BOILER MAKERS'
BLACKSMITHS'
ENGINEERS'
SHOP

ETC., ETC., ETC.

Of the best material, best workmanship and at the lowest rates.

CASTINGS AND MACHINERY FOR VARIOUS PURPOSES.

AGRICULTURAL
ARCHITECTURAL
BELT PULLEYS
BALANCE WHEELS
INSIDE GEARING
JACK SCREWS
MINING CARS
MANTLE GRATES

BALANCE BOBS	MITRE GEARING
BEVEL GEARING	MARBLE CUTTING MACH.
BARK MILL MACHIN'Y	MALT MILL MACHINERY
CONICAL PULLEYS	MANDRELS
CAR WHEELS	MELTING KETTLES
CEMETERY FENCES AND GATES	OIL-WELL BORING MACHINERY
COINING MACHINERY	ORDNANCE
CLAMP BLOCKS	OIL COOLERS
CANDLE MOLDS	PULLEY BALAN. WHEELS
CAST-IRON WATER PIPE	PUMPING BOBS
COPPER BOILER TUBES	PICKETS
DOOR SCRAPERS	PICKET HEADS
DERRICK IRONS	PINION RACKS
ELLIPTICAL GEARING	PILE-DRIVING MACH'Y
FLANGES—PULLEY	POWDER MILL MACH'Y
FLANGES—WHEEL	PAPER MILL MACHIN'Y
FLY WHEELS	PLUMBERS' GOODS
FRICTION GEARING	PILLOW BLOCKS
FRICTION BEVEL GEARING	RANGE—GRATE BARS
	RICE MILL MACHINERY
FAN BLOWERS	SPIDERS
FANS—EXHAUST	SEGMENT GEARING
FORGE BACKS	SPUR GEARING
GARDEN & LAWN FENCE	SOAP KETTLES
GREEN HOUSE FITTINGS	TALLOW COOLERS
GENERAL HARDWARE	TUYERES IRONS
GUDGEONS	UMBRELLA RACKS
GAS PIPES	WINGED JOURNALS
HAND WHEEES	WAGON BOXES
HANGERS	WROUGHT IRON WATER PIPES
HORSE POWERS	
IRON BOILER TUBES	WHEAT SCREENS

ETC., ETC., ETC.

Of the best material, best workmanship, and at the lowest rates.

The most approved designs, accurate drawings, careful estimates and deliberate counsel will be furnished our patrons with respect to any machinery which they may desire.

PATTERN LIST.

N. B.--The diameter of the Spur, Bevel, and Mitre Wheels are measured on the pitch line, and will be the given sizes when cast.

In ordering any wheel on the list, state the diameter, pitch, face, number of cogs, and particulars of shaft or core for hub.

Spur wheels and segments can be made deeper when required.

GEAR WHEELS.

Table to find the diameter of a wheel, the pitch and number of cogs being given; or, to find the number of cogs, the diameter and pitch being given.

Pitch. Inches.	Diameter.	No. of cogs.	Pitch. Inches.	Diameter.	No. of cogs.
½	.1592	6.2832	2	.6366	1 5708
⅝	.1989	4.0266	2⅛	.6764	1.4784
¾	.2387	4.1888	2¼	.7162	1.3963
⅞	.2785	4.5904	2⅜	.7560	1.3228
1	.3183	3.1416	2½	.7958	1.2566
1⅛	.3581	2.7926	2¾	.8754	1.1333
1¼	.3979	2.5132	3	.9547	1.0472
1⅜	.4377	2.2848	3½	1.1141	.8976
1	.4776	2.0944	4	1.2732	.7854
1¾	.5172	1.9264	4½	1.4270	.6981
1⅛	.5570	1.7952	5	1.5915	.6283
1	.5968	1.6755	6	1.9095	.5236

To find the diameter in inches, multiply the number of cogs by the tabular number in the second column corresponding to the given pitch.

To find the number of cogs, multiply the diameter by the tabular number in the third column corresponding to the given pitch.

BEVEL WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	P. L. to Back of Hub.	Wgt. Lbs.	Remarks.
1 11-16	½	11-16	11			
2 5-16	"	"	15			
1 15-16	½	1	12			
8 ⅝	"	"	54			
2 11-16	½	1	17			
8	"	"	51			
2 ⅛	9-16	⅞	12			
3 ¼	"	"	18			
3 3-16	9-16	1 ¼	19	13-16		
20	"	"	120	1 ¾		
2 ⅜	⅝	1	12			
4 ¾	"	"	24			
2 ¾	⅝	1 ¼	14			
4 ⅛	"	"	21			
3	⅝	1	15	⅜		
5	"	"	25	1		
3 ⅜	¾	1 ¾	15			
8 ½	"	"	37			
4 5-16	¾	1 ¾	18			
8 ⅝	"	"	36			
7 ½	⅞	1 ¾	27	1		
10	"	"	36	1 ⅜		

BEVEL WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	P. L. to Back of Hub.	Wgt. Lbs.	Remarks.
4 3/4	15-16	2 3/8	16	1/4		
15 1/4	"	"	52	1 1/2		
2 3/4	1	3/4	8	"		
3 13-16	"	"	12	"		
6	1	2	19	3/4		
8 9-10	"	"	28	"		
5 1/8	1 1/4	3	13	1/2		
15 1/8	"	"	38	2 3/8		
7 1/8	1 1/4	2 1/2	18	3/8		
26 1/4	"	"	66	3		
8	1 1/4	2 1/2	20	1/2		
18	"	"	45	2 3/4		
8	1 1/4	2 1/2	20	3/4		
18	"	"	45	2 3/8		
10	1 1/4	3	25	7/8		
20 1/4	"	"	51	2 3/8		
10	1 1/4	3 1/2	25	1/2		
30	"	"	75	3 3/4		
11 7/8	1 1/4	2 1/2	30	3/4		
36 1/4	"	"	91	3		
12	1 1/4	3 1/2	30	5/8		
24 1/4	"	"	61	2 1/8		
24 1/4	"	"	61	5 1/2		

BEVEL WHEELS.

Diameter. Inches	Pitch. Inches.	Face. Inches.	No. Teeth.	P. L. to Back of Hub.	Wgt. Lbs.	Remarks.
7 7/8	1 3/8	3	18	3/8		
24	"	"	55	2 7/8		
12 3/4	1 7-16	4 1/2	28			
96	"	"	200			8 Segments.
6 2-16	1 1/2	3 1/2	13	3/4		
18 6-10	"	"	39	3		
8 5/8	1 1/2	3	18	1 1/2		
17 1/4	"	"	36	3 1/8		
9 1-16	1 1/2	4	16	5 1/8		
36 1/4	"	"	76	4 3/4		
9 1/2	1 1/2	4 3/4	20			
77 3/8	"	"	162	11		
11 5/8	1 1/2	3	24	1 7/8		
15 1/2	"	"	32	2 3/8		
14 8-10	1 1/2	4	31	1/2		
59 7-10	"	"	125	5 1/4		
12 1/4	1 3/4	3	22			
260 3/4	"	"	468			26 Segments.
6 5/8	1 3/4	6	12	1/2		
53 1/2	"	"	96	4 3/4		
12 1/4	1 3/4	4 1/2	22	1 1/8		
49	"	"	88	5 1/8		

BEVEL WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	P. L. to Back of Hub.	Wgt. Lbs.	Remarks.
14	1 3/4	4 1/2	25	1		
28	"	"	50	3 1/2		
36	1 3/4	4 1/2	66	6 5/8		
12	"	"	22	1 7/8		
24	1 3/4	4 1/2	43	3 1/2		
17 13-16	"	"	32	2 7/8		
60	1 3/4	5	108			
6 3/4	"	"	12			
7 3-16	1 7/8	4	12	5/8		
34	"	"	57			
7 5/8	2	3 3/4	12	1/2		
29 1/4	"	"	46	3 1/4		
12 3-32	2	6	19	1/2		
76 1/8	"	"	90			6 Segments.
14	2	4 1/2	22	1 7/8		
28	"	"	44	7 1/4		Mortice.
14 1/2	2	5	23	3 1/8		
20 3/4	"	"	33	1 1/2		
15 1/4	2	5	24			
29 9-10	"	"	47	3 1/4		
16 1/8	2 1/8	5	24	1 1/8		
48 1/2	"	"	72	5 3/4		
12 1/4	2 1/4	6	17	7/8		
24 1/2	"	"	34	4		

BEVEL WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	P. L. to Back of Hub.	Wgt. Lbs.	Remarks.
12 1/4	2 1/4	6	17	1 5/8		
31 1/2	"	"	44	3 3/4		
12 7/8	2 1/4	5	18	1		
18 5/8	"	"	26	2 3/4		
19 9-39	2 1/4	5	27	2 1/8		
42 26-32	"	"	60	6 1/4		Mortice.
12 9-16	2 1/4	5	18			
51 1/2	"	"	72	6 3/4		Mortice.
24 1/4	2 1/4	5	34	2		
55 21-31	"	"	78	6		
31 1/2	2 1/4	5	44	2		
51 1/2	"	"	72	6		Mortice.
15 1/8	2 1/2	6	19	3/4		
60 1/2	"	"	76	7		
18 1/2	2 1/2	6	23	1 1/2		
37 3/4	"	"	47	5 3/8		
19 5/8	2 1/2	5	25			
57 5-16	"	"	72	6 3/4		Mortice.
23 7/8	2 1/2	5 1/2	30	1		
54 1/8	"	"	68	4		
25 7-16	2 1/2	7	32	3 3/8		
53 5-16	"	"	67	5 3/4		
28	2 1/2	8	35	2 3/8		
48 1/2	"	"	61	10		Mortice

BEVEL WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	P. L. to Back of Hub.	Wgt. Lbs.	Remarks.
49.89	2 3/4	8	57	5 1/2		
59.52	"	"	68	4 1/2		
47 5-16	2 3/4	7	54	7		
23 11-16	"	"	27	3 3/8		
13 3/8	3	8	14			
36 1/4	"	"	38	6 1/8		

MITRE WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	P. L. to Back of Hub.	Wgt. Lbs.	Remarks.
2 ¾	5-16	½	27			
3 ⅞	5 1-16	¾	40			
2 ½	⅜	⅜	19			
2 11-16	⅜	13-16	21			
2 9-16	½	⅞	16			
3 ⅞	½	1	25			
4 ½	½	⅞	28			
5	½	1	30			
5 ½	½	1 ⅜	30	½		
3 ½	⅝	1 ⅜	18			
4	⅝	1 ¼	20			
5 ⅜	⅝	1 ½	27			
6	⅝	1 ½	30	¾		
7 ½	⅝	1 3-16	37			
4	¾	1 ¼	16	9-16		
5 ¾	¾	1 ⅛	24			
7 ⅞	¾	1 ½	33			
9	¾	2	38			
8	⅞	2	29	⅞		
7 5-16	15-16	2 ½	25	9-16		
13	1	2 ¼	43	2 ¼		
12	1 ¼	3	30	1 ¾		
6	1 ¼	2	15	1 ⅜		
16	1 ¼	2 ¾	40	2 ¼		
68	1 ⅜	2 ¼	14			
8	1 ⅜	2 ½	18	1 ⅝		
18	1 ⅜	3 ½	41	2 ⅛		
8 11-32	1 ½	2	18	1 ¾		
20	1 ⅝	4 ½	39	2 ¼		
20	1 ⅝	4 ½	39	3 ¾		Mortice.
8 5-16	1 ¾	2 ⅛	15	1 ½		
24	1 ¾	5	43	3		
20 ¼	2	3 ½	32	2		
24 ⅞	2	6	39	2 ⅝		
30	2	6	47	4 ½		
30	2	6	47	2 ⅝		Mortice.
28	2	5 ½	44	3 ¼		
14 ¾	2 ⅛	5	22			
36	2 ¼	6	50	1 ¾		
36 ¾	2 ¾	8	42	4 ⅜		
36 ¾	2 ¾	8	42	6		Mortice.

SPUR WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches	No. Teeth.	Wgt. Lbs.	Remarks.
6 5-16	¼	1	71		
2 ⅜	¼	1	26		
4	5-16	½	36		
1 ⅞	⅜	2 ¼	15		
2 9-16	⅜	¾	22		
3 ½	⅜	1	30		
4 ⅜	⅜	1 ¼	37		
13 ¼	⅜	¾	112		
4 11-16	7-16	⅞	33		
13 5-16	7-16	⅞	93		
2 ¼	½	1 ⅛	14		
2 ⅝	½	1 ⅜	17		
3	½	⅞	18		
3	½	1	19		
3 9-16	½	1 ⅜	22		
3 ⅝	½	1	23		
3 11-16	½	1	23		
2 ¾	½	1 ¼	16		
3 ¾	½	1 ¾	24		
3 ⅞	½	1 ⅝	24		
3 15-16	½	1 ¾	25		
3 ⅜	½	¾	22		
4 ⅛	½	1	26		
5 ⅞	½	1	39		
6 ⅝	½	¾	43		
6 ⅞	½	1 3-16	45		
8	½	1 1-16	50		
9 3-16	½	1 ¾	58		
9 13-16	½	1 ½	60		
12 11-16	½	1 ¾	80		
8	½	1 ½	48		
2	⅝	1 ½	10		
2 ⅛	⅝	1 ⅛	11		
2 ⅞	⅝	1 ¼	14		
2 ¾	⅝	1 ½	14		
2 ⅝	⅝	1 ½	14		
4 ⅞	⅝	1 ¼	25		
2 15-16	⅝	3 ¼	15		
6 ¾	⅝	1 ½	34		
7 9-16	⅝	1 ¼	39		
7 9-16	⅝	1 ½	38		
9 15-16	⅝	1 ¼	50		
2 3-16	11-16	1 ½	10		Round Points.
2 ¼	11-16	1 ⅝	10		

SPUR WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	Wgt. Lbs.	Remarks.
3 ½	11–16	1 ¾	16		
4 9–16	11–16	1 ½	21		
5 ⅜	11–16	1 ½	24		
5 ¾	11–16	1 ½	27		
2 ⅝	¾	¾	10		
2 ⅞	¾	2 ½	12		
3 ¾	¾	1 ¼	16		
3 1–16	¾	⅞	13		
4 1–16	¾	2	17		
3 3–16	¾	2 ¼	13		
3 13–16	¾	4 ⅛	16		
5	¾	¾	21		
5 ⅜	¾	2	22		
5 ⅝	¾	1 ¾	23		
7 6–10	¾	2 ¾	32		
7 ¾	¾	4 ⅛	32		
8	¾	1	34		
8	¾	1 ½	36		
9 3–16	¾	1 ¾	39		
10 9–16	¾	2	44		
12 3–16	¾	2	51		
14 9–16	¾	1 ½	61		
17 ⅛	¾	2 ¼	72		
19 ⅝	¾	2 ¼	84		
20	¾	1	85		
21 ¾	¾	2	91		
12 ⅛	13–16	2	48		
21	13–16	1 ½	83		
3 ¼	⅞	1 ¾	12		
3 ¾	⅞	2	12		
3 9–16	⅞	2 ¾	13		
3 ⅞	⅞	1 ½	14		
3 ⅞	⅞	2 ½	14		
4 ⅜	⅞	1 ⅝	16		
5	⅞	3	18		
4 11–16	⅞	1 ½	17		
6 ⅞	⅞	1 ¼	23		
7 ⅜	⅞	1 ½	27		
12 ⅝	⅞	2	45		
14 ¼	⅞	1 ¾	51		
14 7–16	⅞	1 ¾	52		
15 ¾	⅞	2	56		
21 3–16	⅞	5	76		
22 ½	⅞	1 ½	81		

SPUR WHEELS

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	Wgt. Lbs.	Remarks.
23 ¼	⅞	1 ¾	86		
25 ⅛	⅞	2 ½	90		
2 ⅝	15-16	1 ¼	9		
2 ⅝	15-16	1 ½	9		
3 ⅝	15-16	2	12		
3 7-16	15-16	2	12		
6 ⅞	15-16	1 ½	23		
2 13-16	1	3 ½	9		
3 ½	1	3	11		
4 ⅛	1	2 ¼	13		
4 ¼	1	3	13		
4 5-16	1	3 ½	14		
4 7-16	1	3	14		
4 ½	1	3 ⅞	14		
5 ¼	1	3 ¼	16		
5 ⅝	1	1 ½	18		
6	1	3	19		
6 ⅛	1	1 ½	19		
6 ⅛	1	2	19		
6 ⅜	1	2	20		
6 ⅜	1	1 ⅝	20		
7 ⅛	1	1	22		
7 ⅜	1	3 ½	23		
8 ¾	1	2 ½	28		
9 ½	1	1 ½	30		
12	1	2	38		
15	1	2	47		
15 ⅛	1	3 ¼	47		
23 ⅞	1	2	75		
24	1	3	75		
28	1	2	88		
30 3-16	1	2	95		
36	1	2	113		
36	1	3	113		
10	1	3	32		
40 ¾	1	1 ¾	128		8 Segments.
3 ⅞	11-16	2 ¼	12		
4 ⅞	11-16	2 ¾	13		
9	11-16	1 ½	27		
11 11-16	11-16	2 ⅛	13		
5	11-16	3 ½	14		
5 ⅜	11-16	2 ½	15		
8 ½	11-16	4	24		
11 1-16	11-16	2 ½	31		

SPUR WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	Wgt. Lbs.	Remarks.
13 7/8	11-16	2	38		
15	11-16	3	42		
18	11-16	2 1/2	50		
19 3/4	11-16	2	54		
4 3/8	13-16	2 1/2	12		
4 7/8	13-16	2	12		
4 3/8	1 1/4	2	11		
4 3/4	1 1/4	3 3/4	12		
5 3-16	1 1/4	4	13		
5 1/2	1 1/4	3	14		
5 7/8	1 1/4	3 3/4	15		
6 1/4	1 1/4	3	16		
6 7/8	1 1/4	3 3/4	18		
7 7/8	1 1/4	3	20		
8	1 1/4	4 1/2	20		
8 7/8	1 1/4	4	22		
9 1/2	1 1/4	3	24		
10	1 1/4	5	25		
13 7/8	1 1/4	3 1/2	35		
20 5/8	1 1/4	3	52		
28	1 1/4	4 1/2	70		
32 3/4	1 1/4	4	81		
42 1/8	1 1/4	3 1/2	106		
60	1 1/4	3 1/2	151		8 Arms.
101 7/8	1 1/4	4	256		8 Segments.
5 1/8	1 3/8	3	12		
4 3/8	1 1/2	4 3/4	9		
5 5/8	1 1/2	1 1/2	12		Star.
5 3/4	1 1/2	3 1/2	12		
6	1 1/2	4 1/4	13		
6 1/4	1 1/2	4 1/2	13		
6 5/8	1 1/2	4 1/2	14		
7 3-16	1 1/2	4 1/2	15		
7 3-16	1 1/2	6 1/2	15		
7 11-16	1 1/2	3 3/4	16		
9 1-16	1 1/2	4 1/2	19		
10	1 1/2	2	21		
21 1/2	1 1/2	4 1/2	45		
25 7/8	1 1/2	3	54		
50 1/8	1 1/2	4 1/2	105		
195	1 1/2	4	408		24 Segments.
7 7/8	1 5/8	5	15		
8 3/4	1 5/8	4 1/2	17		
5 5/8	1 3/4	3 1/2	10		

SPUR WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	Wgt. Lbs.	Remarks.
6 3/4	1 3/4	4 1/2	11		
6 3/4	1 3/4	3 3/4	12		Round Points.
7 3/4	1 3/4	6	14		
7 3/4	1 3/4	3 1/2	14		
7 3/4	1 3/4	5	14		
7 7/8	1 3/4	4 1/2	14		
8 3/4	1 3/4	4	15		
12 7/8	1 3/4	4	23		Round Points.
14	1 3/4	3 1/2	25		
19	1 3/4	3 1/2	34		To run in Mortice.
25	1 3/4	3 1/2	45		
30 1-16	1 3/4	4 1/2	54		
33 3/8	1 3/4	3 1/2	60		
42 5-16	1 3/4	4 1/2	76		
7 11-16	1 7/8	4	13		Round Points.
8 3/8	1 7/8	6	14		
218	1 7/8	5	378		18 Segments.
6 1/2	2	3	10		Star.
16 1/2	2	4	26		
19 5/8	2	4	31		
36 1/4	2	6	57		8 Arms.
5 1/4	2 1-16	1 3/8	8		Star.
6 3/4	2 1/8	1 1/2	10		Star.
40	2 3-16	5	57		
8 1/2	2 1/4	6 1/4	12		
10 5/8	2 1/4	5 1/2	15		
10 3/4	2 1/4	6	15		
11 1/2	2 1/4	6 1/2	16		
12 3/4	2 1/4	6 1/4	18		
13 5/8	2 1/4	6	19		
14 1/4	2 1/4	7	20		To run in Mortice.
15 3/4	2 1/4	7	22		
15 1/8	2 1/4	6 1/2	22		
17 3-16	2 1/4	5	24		
18 9-16	2 1/4	5	26		
24 3/8	2 1/4	5	34		
28	2 1/4	5	39		
35 3/4	2 1/4	6	50		
38 5/8	2 1/4	8	54		Mortice.
40	2 1/4	4	56		
41 1/2	2 1/4	6	58		
48	2 1/4	5	67		
48	2 1/4	6	67		
60 1/4	2 1/4	6	84		

SPUR WHEELS.

Diameser. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	Wgt. Lbs.	Remarks.
67 1/4	2 1/2	6	94		
72 1/4	2 1/2	6	101		
75	2 1/2	4	104		8 Segments.
94 11-32	2 1/2	4 1/2	132		6 "
143 1/4	2 1/2	6	200		10 " Teeth inside.
195	2 1/2	5	272		17 Segments.
240 5/8	2 1/2	6	336		16 "
300 3/4	2 1/2	5	420		28 "
309 3/8	2 1/2	5	432		24 "
361	2 1/2	6	504		24 "
361	2 1/2	5	504		36 "
420	2 1/2	6	600		40 "
481 9-32	2 1/2	6	672		32 "
15 3/8	2 4-10	6	20		
235 1/4	2 4-10	6	418		22 Segments.
12	2 1/2	10 1/2	15		
12 11-16	2 1/2	6 1/2	16		
15	2 1/2	5	19		
18 1/4	2 1/2	6 1/2	23		
20 11-16	2 1/2	6	26		
28 5/8	2 1/2	10 1/2	36		
32 1/4	2 1/2	6 1/2	41		
85 3/4	2 1/2	6	108		
300 3/4	2 1/2	6	378		21 Segments.
312	2 1/2	7 3/8	420		28 "
5 1/4	2 5/8	3 1/8	6		Round Points.
38 1/8	2 9-16	7	47		
165 3/4	2 13-24	7	204		12 Segments.
7 1/2	2 3/4	2 7/8	8		Round Points.
8 3/4	2 3/4	7	10		
15 5/8	2 3/4	5	18		
16 3/4	2 3/4	8 1/2	19		
23 5/8	2 3/4	9 1/2	27		
14 1/8	2 3/4	8 1/2	16		
36 3/4	2 3/4	6 3/4	42		
60 1/2	2 3/4	8	69		
84	2 3/4	8 1/2	96		
17 1/2	3	8 1/2	18		
28 5/8	3	9	30		
36 1/4	3	9	38		
47 3/4	3	8	50		
107	3	8	112		8 Segments (for arms)
152 3/4	3	11	160		10 Segments.
240 3/4	3	7	252		18 "

SPUR WHEELS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	Wgt. Lbs.	Remarks.
42 ¼	3 ⅛	8	42		
18	3 ½	11	16		
24 ½	3 ½	10 ½	22		
25 ⅞	3 ½	10 ¼	23		
30 ¼	3 ½	10	27		
36 ¾	3 ½	10	33		
84 ¾	3 ½	10	76		
120 ½	3 ½	10	108		
35 ¾	4	14 ½	28		
43 ¼	4	10 ¼	34		
104 ½	4	10	82		
149	4	14 ½	117		
27 ¼	5	17	17		
55 ¾	5	10 ½	35		
135 ⅜	5	17	85		

WORMS.

Diameter. Inches.	Pitch. Inches.	Face. Inches.	No. Teeth.	Wgt. Lbs	Remarks.
7 7/8 2	1 "	1 1/2	25		
21 1/2 3 1/2	1 1/4 "	2 1/2	54		
30 1/8 7 1/8	1 5-16 "	3 1/2	72		
36 10	1 21-32	4 3/4	68		Double thread.
18 1/8 5 1/2	1 1/2	3 1/2	38		
18 1/2 5 1/2	1 7/8	3 1/2	30		
36 3/4 12	2 3/4	7	42		

RACKS.

Length. Inches.	Pitch. Inches.	Face. Inches.	Wgt Lbs.	Remarks.
30 1/2	1 1/8	3		
35 3/4	1 3-16	2 1/2		
29 5/8	1 1/4	3 3/8		
24 3/4	1 1/4	3		
30	1 1/4	3		Double.
33 1/2	1 1/4	3		
36	1 1/4	3		
24	1 3/8	2		
21	1 1/2	4		
48	1 1/2	4		
39	1 3/4	4 3/4		

Force Developed in Heat and Water Power.

"Force" says Professor Pierce, "seems to have a spiritual origin." Its actual nature science has not determined. We recognize the existence of force through the observed effects it produces. Force is the universal source of change, always operating in connection with matter and ever persistent in maintaining its integrity, so that the sum of its efforts is constant. It is developed in various forms—as in attraction and repulsion—in motion and its equivalents, heat, light, electricity and galvanism. It acts upon the atom, molecule, particle, body aggregate, world, sun and systems. Developed as heat from the sun, force lifts the waters to the clouds, whence by the force of gravity they descend to earth and flow as a *mechanical power* in their course back to the sea. Also coming in the forms of heat and light from the sun, force induces vegetation and builds up forests. These, in the cycles of change, are prostrated and buried for ages; but in their sepulcher embrace their parent force which in the meantime transforms their entombed mass into coal, from whose combustion it rises Phœnix-like in all its integrity and pristine energy.

Heat and its Mechanical Equivalent.

Modern investigation has determined that heat and mechanical energy are mutually convertible.

The unit of heat or Thermal unit is that quantity of heat necessary to raise one pound of water through 1° at its temperature of maximum density; or from 39° to 40° Fahr.

The mechanical equivalent of a *Thermal Unit* is 772 "foot pounds." A "foot pound" being the amount of energy necessary to raise one pound weight vertically through a space of one foot.

Heat of Evaporation.

The heat necessary to evaporate one pound of water into dry steam from and at 212° Fahr. is 966 Thermal units. The mechanical equivalent of which is

$$966 \times 772 = 745{,}752 \text{ "foot pounds."}$$

The combustion of one pound of carbon making carbonic acid will evaporate 15 pounds of water into dry steam from and at 212° Fahr. so that its mechanical equivalent is

$$745752 \times 15 = 11,186,280 \text{ "foot pounds."}$$

But the combustion of one pound of carbon making carbonic oxide will evaporate only 4.61 pounds of water, showing a loss by incomplete combustion of nearly seventy per cent.

Total and Latent Heat of Evaporation.

The *Total Heat* of evaporation of water is that quantity of heat necessary to raise one pound of water from 32° Fahr. to a given temperature.

The *Latent Heat* of evaporation of water is the quantity of heat necessary to evaporate a pound of water at a given temperature. H is employed to represent the total heat of evaporation; L the latent heat of evaporation, and t° the given temperature. Then as determined by M. Regnault

$$H = 1081.4 + .305\ t^\circ \qquad (1)$$

$$\text{and } L = 1115.2 - 708\ t^\circ \qquad (2)$$

Thus the Thermal units requisite to raise one pound of water from 32° to 212° Fahr. are

$$H - L = 180.95^\circ \text{ as follows:}$$

$$H = 1081\ 4^\circ + .305 \times 212^\circ = 1146.06^\circ$$

$$L = 1115.2^\circ - .708 \times 212^\circ = 965.11^\circ$$

$$1146.06^\circ - 965.11^\circ = 180.95^\circ \text{ Thermal units sought.}$$

The sensible heat is 212° − 32° = 180° which is .95° less, than the Thermal units. When the given temperature is not very high, the sensible heat may in practice be employed for the Thermal units without appreciable error.

Relations Between Pressure, Temperature, Density and Volume.

When the pressure per square inch is 25 pounds and upward:

$$\log. p = 4.5\ (\log. t - 2.07) \qquad (3)$$

$$\log. D = .941 \log. p - 2.519 \qquad (4)$$

$$\log. V = 2.519 - .941 \log. p \qquad (5)$$

$$\log. n = 4.31388 - .941 \log. p \qquad (6)$$

In the sixth (6) formula *n* represents the relative volume of saturated steam produced from one volume of water at 62° Fahr.

The values of *p*, ∢, *D*, *V*, *n*, H and L will be found in the following Tables:

TABLE I.

Clarke.

PROPERTIES OF SATURATED STEAM FROM 32°.

Temperature t°.....	Pressure per square inch. lbs.........	Total heat from water at 32° Fahr...	Latent Heat.	Weight of 100 cubic feet. lbs..........	Volume of one pound vapor. cu. ft.....	Rel. vol. of steam from 1 cu. ft. water.
32°	.089	1091.2°	1091.7°	.031	3226.	201157.
35	.100	1092.1	1089.6	.034	2941.	183386.
40	.122	1093.6	1086.0	.041	2439.	152084.
45	.147	1095.1	1082.4	.049	2041.	127267.
50	.178	1096.6	1078.9	.059	1695.	105692.
55	.214	1098 2	1075.4	.070	1429.	89105.
60	.254	1099.7	1071.8	.082	1220.	76073.
65	.304	1101.2	1068.3	.097	1031.	64288.
70	.360	1102.8	1064.7	.114	877.2	54698.
75	.427	1104.3	1061.2	.134	746.3	46535.
80	.503	1105.8	1057.6	.156	641.0	40170.
85	.592	1107.3	1054.1	.182	549.5	39969.
90	.693	1108.9	1050.6	.212	471.7	29413.
95	.809	1110.4	1047.1	.245	408.2	25453.
100	.942	1111.9	1043.5	.283	353.4	22036.

TABLE 1.

Clarke.

PROPERTIES OF SATURATED STEAM.

Pressure, lbs.......	Temperature Fahr...	Total heat from water at 32° Fahr...	Latent heat Fahr...	Density or Weight of cubic feet, lbs..	Volumne of 1 lb of steam, cubic feet.	Relative Vol. or cu. ft. of steam from 1 cu. ft. of water...
1	102.1°	1112.5°	1042.9°	.0030	330.36	20600.
2	126.3	1119.7	1025.8	.0058	172.08	10730.
3	141.6	1124.6	1015.0	.0085	117.52	7327.
4	153.1	1128.1	1006.8	.0112	89.62	5589.
5	162.3	1130.9	1000.3	.0138	72.66	4530.
6	170.2	1133.3	994.7	.0163	61.21	3816.
7	176.9	1135.3	990.0	.0189	59.94	3301.
8	182.9	1137.2	985.7	.0214	46.69	2911.
9	188.3	1138.8	981.9	.0239	41.79	2606.
10	193.3	1140.3	978.4	.0264	37.84	2360.
11	197.8	1141.7	975.2	.0289	34.63	2157.
12	202.0	1143.0	972.2	.0314	31.88	1988.
13	205.9	1144.2	969.4	.0338	29.57	1844.
14	209.6	1145.3	966.8	.0362	27.61	1721.
14.7	212.0	1146.1	965.2	.0380	26.36	1642.
15	213.1	1146.4	964.3	.0387	25.85	1611.
16	216.3	1147.4	962.1	.0411	24.32	1516.
17	219.6	1148.3	959.8	.0435	22.96	1432.
18	222.4	1149.2	957.7	.0459	21.78	1357.
19	225.3	1150.1	955.7	.0483	20.70	1290.
20	228.0	1150.9	952.8	.0507	19.72	1229.
21	230.6	1151.7	951.3	.0531	18.84	1174.
22	233.1	1152.5	949.9	.0555	18 03	1123.
23	235.5	1153.2	948.5	.0580	17.26	1075.
24	237.8	1153.9	946.9	.0601	16.64	1036.
25	240.1	1154.6	945.3	.0625	15.99	996.
26	242.3	1155.3	943.7	.0650	15.38	958.

TABLE 1. (Continued.)

PROPERTIES OF SATURATED STEAM.

P	T	H from 32°	L	D	V	n
30	250.4°	1157.8°	937.9°	.0743	13.46	838
35	259.3	1160.5	931.6	.0858	11.65	726
40	267.3	1162.9	926.0	.0974	10.27	640
45	274.4	1165.1	920.9	.1089	9.18	572
50	281.0	1167.1	916.3	.1202	8.31	518
55	287.1	1169.0	912.0	.1314	7.61	474
60	292.7	1170.7	908.0	.1425	7.01	437
65	298.0	1172.3	904.2	.1538	6.49	405
70	302.9	1173.8	900.8	.1648	6.07	378
75	307.5	1175.2	897.5	.1759	5.68	353
80	312.0	1176.5	894.3	.1869	5.35	333
85	316.1	1177.9	891.4	.1980	5.05	314
90	320.2	1179.1	888.5	.2089	4.79	298
100	327.9	1181.4	883.1	.2307	4.33	270
110	334.6	1183.5	878.3	.2521	3.97	247
120	341.1	1185.4	873.7	.2738	3.65	227
130	347.2	1187.3	869.4	.2955	3.38	211
140	352.9	1189.0	865.4	.3162	3 16	197
150	358.3	1190.7	861.5	.3377	2.96	184
160	363.4	1192.2	857.9	.3590	2.79	174
170	368.2	1193.7	854.5	.3798	2.63	164
180	372.9	1195.1	851.3	.4009	2.49	155
190	377.5	1196.5	848.0	.4222	2.37	148
200	381.7	1197.8	845.0	.4431	2.26	141
220	389.9	1200.3	839.2	.4842	2.06	129
250	401.1	1203.7	831.2	.5464	1.83	114
300	417.5	1208.7	819.6	.6486	1.54	96
400	444.9	1217.1	800.2	.8502	1.18	73

FUEL.

Wood and coal constitute the fuel mostly employed in heat motors. Each of these has a *mechanical* and a commercial value. The standard of measure of the mechanical value of fuel is water estimated in pounds, which one pound of the combustible is capable of evaporating from and at 212° Fahr. at atmospheric pressure. The standard of measure of the commercial value of fuel, aside from speculative considerations, is that of its economical value estimated by the *maximum* effect produced at *minimum* cost.

The ratio of the mechanical value of one fuel to that of a better quality is greater than the ratio of the commercial value of the former to that of the latter. For illustration, assume that a pound of coal, whose cost is eight dollars a ton, will evaporate five pounds of water, while a pound of coal, whose cost is sixteen dollars a ton, will evaporate ten pounds of water, and that the cost of transportation and handling is one dollar a ton. Here, to perform the same work, two tons of the former costing *eighteen* (18) dollars are required to one ton of the latter costing seventeen (17) dollars, making a gain of one dollar or six per cent. in favor of the better quality of coal. Thus, by ascertaining the mechanical values of fuels, their relative commercial or economical values are readily determined.

TABLE 2.

Clarke, et al.

HEATING POWER OF FUELS.

FUEL.	Heating Power of 1 lb. of Fuel.		
	Water Evaporated for 1 lb. of Fuel From and at 212°.	Units of Heat....	Mechanical Equivalent foot lbs....
Coal, Anthracite (pure carbon.)	15.	14.490	11,186,280
" " (in practice.)	10.86	10.491	8,099,052
" Ilamma (bituminous.)	9.61	9.360	7,225,920
" Black Diamond "	8.71	8.414	6,495,608
" Independent "	7.16	6.917	5,339,924
" Best Welsh "	17.07	16 495	12,734,140
" Sydney "	11.23	10.848	8,374,656
" Lignite (perfect) "	12.10	11.678	9,015,416
Coke.	14.02	13.550	10,460,600
Wood, Charcoal (dry.)	13.13	12.696	9,801,313
Wood (perfectly dry.)	8.02	7.792	6,015,424
" (25 per cent. moisture)	6.02	5.815	4,489,180
Petroleum.	20.33	20.240	15,625,280
Coal, Gas.	35 50	34.292	26,473,424
Hydrogen.	64.20	62.032	47,888,704

A cord of pine wood, that is of pine wood cut up and piled, measures $4 \times 4 \times 8 = 128$ cubic feet. Its weight in ordinary condition, containing, say 25 per cent. of moisture, is 2700 pounds. Its heating power is about that of Independent Coal.

STEAM MACHINERY.

BOILER TESTS.

The efficiency of a boiler may readily be determined when the evaporative power of the combustible employed in it is known. The relative efficiency of two or more boilers can be ascertained by the use of the same quality of fuel without this knowledge. The mode of testing a boiler is as follows: From the total heat of the generated steam due to its mean total pressure, deduct the difference between the total heat and latent heat of the feed water before entering the boiler, and divide the remainder by the latent heat of steam at 212° Fahr. Multiply the quotient by the total number of pounds of water evaporated and divide this product by the total number of pounds of coal or combustible. This quotient represents the number of pounds of water evaporated per pound of coal or combustible.

Question. A boiler supplying steam under a pressure of one hundred and twenty-five pounds per square inch, consumes one ton (2000 pounds) of coal and evaporates fifteen thousand pounds of water. The temperature of the feed water before entering the boiler is 102.1° Fahr. Required the equivalent evaporation per pound of coal from and at 212° Fahr.

Answer. In Table 1, first column, find one hundred and twenty-five pounds pressure, opposite which in *total heat* column will be found 1186.4°, and for temperature feed water will be total heat, 1112.5; latent heat, 1042.9. Then $1112.5° - 1042.9° = 69.6°$; and $1186.4° - 69.6° = 1116.8°$; $1116.8 \times 15000 \div 966 \times 2000 = 8.67$ pounds of water per pound of coal.

In practice as hitherto remarked under the heading of total and latent heat of evaporation, when the given temperature is not very high, the sensible heat imparted may be employed for thermal units without appreciable error.

Adopting which, the following is the solution of the preceding problem, viz: By Table 1, the sensible heat corresponding to 125 pounds pressure is 344.2°. From which deduct 102.1°, the temperature of the feed water. $344.2° - 102.1° = 242.1°$. To this difference add the latent heat for 344.2° (Table 1). $242.1° + 871.5° = 1113.6°$. Then proceed as above $1113.6 \times 15000 \div 966 \times 2000 = 8.65$ pounds of water evaporated per pound of coal.

PRIMING. When *priming* occurs, a Calorimeter is required to determine the quantity of heat carried out in the priming water.

CALORIMETER. The most simple, direct and most accurate Calorimeter is that of Professor G. V. Hirn. It consists of a plain wooden barrel provided with a stirring apparatus, and a drain pipe at the bottom. Into a vertical portion of the steam pipe of the boiler, just below the stop-valve, is screwed to the opposite side of the steam pipe a short horizontal piece of ¾-inch pipe having a row of small holes on its lower side. To this is attached a ¾-inch pipe completely felted and running to within two feet of the barrel. At the end of this pipe is attached a ½-inch globe valve, and beyond this is fastened an inch hose about five feet long.

MODE OF USE. The Calorimeter barrel is placed on a platform scale. Water is let into it, accurately weighed and temperature taken. Then the end of the hose being placed in the barrel, steam whose mean pressure during the trial is carefully determined, is let into the water and condensed. The operation is continued until the temperature of the water in the barrel is as much above the temperature of the surrounding atmosphere as it was below it at the beginning of the trial, when the steam is shut off, the water accurately weighed and temperature taken. The difference between the weights of water, and the difference between its temperatures at the beginning and end of the trial, give respectively the weight of the steam and priming conveyed into the barrel, and the thermal units imparted to the water.

STIRRING APPARATUS. The product of the weight of the stirrer and its specific heat is to be added at each trial to the nett weight of the initial water. The specific heat of iron between 32° and 392° is .115, and that of oak .570, water being unity.

The amount of moisture or priming water in steam is estimated by the amount of pure steam contained in a pound of actual steam. The quotient arising from dividing the volume of primed steam by the volume of pure steam of equal weight is termed the "*dryness fraction*" of steam. The heat expended is equal to the product of this dryness fraction and the latent heat of evaporation, increased by the quantity of heat denoted by the difference between the temperature of the feed water and that from and at which the evaporation takes place.

PYROMETER. To determine the waste heat passing off at the chimney, a *Pyrometer* is employed. One of the most simple and efficient of the various Pyrometers is that of Wilson. It consists of some substance of known specific heat, and which is infusible in the heat whose temperature is sought. This is subjected to the action of the heat to be tested, then plunged into water and the rise in temperature noted. In case a bar of platinum, whose weight is one-half that of the water, is used, multiply the rise in the temperature of the water by 67.45, and to the product add the original temperature of the water. This sum will be the temperature sought. In case well baked and thoroughly dry clay, whose weight is one-tenth that of the water, is employed, multiply the rise in the temperature of the water by 46, and add this product to the initial temperature of the water for the temperature sought.

RADIATION. The experiments of B. F. Isherwood, U. S. N., show that the loss of heat by *radiation* in case of a *naked boiler*, housed so as not to be subject to a current of air, or in other words, to be under the average conditions of practice, is about 5 per cent. And that the loss when the boiler is covered with cow-hair felt $1\frac{1}{2}$ inches thick, is only four-tenths (.4) of one per cent.

Relations of the Chimney or Smoke Stack, Grate, Heating Surfaces of Boilers and the Condensers.

The area of the *Smoke-Stack* or *Chimney* (measurement at the top, if pyramidal in form.) is to be about 0.16, or one-sixth the area of the grate. The area of the heating surface varies in different boilers from sixteen to forty times the area of the grate. The average area of the heating surface is about twenty-five times that of the grate. The tubular area in square feet in the Condenser is equal to the square root of the product of the areas of the grate and the heating surface of the boiler.

Strength and Safety of Steam Boilers.

(BY ACT OF CONGRESS APPROVED FEBRUARY 28, 1872.)

"All plates used in steam boilers shall be stamped with the number of pounds equal to the breaking strength per square inch section of the iron. One sixth of the stamped number shall be taken as the safety or working strength of the iron in the boiler. Steam boilers shall be tested with hydrostatic pressure fifty per cent. above the working pressure allowed."

RULE. "Multiply one-sixth (1–6) of the lowest tensile strength found stamped on any plate in the cylindrical shell by the thickness expressed in parts of an inch of the thinnest plate in the same cylindrical shell, and divide the product by the radius, or half the diameter of the shell expressed in inches, and the quotient will be the steam pressure in pounds per square inch allowable in single-riveted boilers, to which add twenty per centum for double riveting."

Reducing the equations derived from this rule to their simplest forms, and we have for single-riveted boilers the following: The pressure in pounds per square inch allowed is equal to one-third the product of the thickness of the shell in inches, and the stamped number of strength divided by the diameter of the shell expressed in inches. And for double-riveted boilers the following: The pressure in pounds per square inch is equal to four-tenths the product of the thickness of the shell in inches, and the stamped number of the iron divided by the diameter of the shell in inches.

Safety Strength of Flues and Tubes From Collapsing by External Pressure.

The pressure in pounds per square inch is equal to the product of the tensile strength (stamped number) per square inch of iron in the flue, and the square of the thickness in inches divided by the product of the diameter of the flue and the square root of the length in feet. This, it is to be observed, is one-fourth of the theoretical pressure.

Horse-Power of Chimney or Smoke-Stack.

NATURAL DRAUGHT.

The horse-power of a *Smoke-Stack* or Chimney (measurement at top,) is ten times its cross-section multiplied by the co-efficient for its height.

TABLE 3.

Nystrom.

HEIGHTS OF CHIMNEYS AND THEIR CO-EFFICIENTS.

Hgt. Chimney.	10	20	30	40	50	60	80	100	140	200	300	400
Co-efficient....	0.5	0.67	0.8	0.91	1.00	1.08	1.23	1.36	1.58	1.86	2.23	2.55

Question. What is the horse-power of a chimney 100 feet high, and whose cross-section is 5 square feet?

Answer. In Table 3 find height of chimney 100, under which will be found 1.36. Then horse-power $= 10 \times 5 \times 1.36 = 68.0$.

Horse-Power in Terms of Pressure, Area of Grate and Heating Surface.

The horse-power in this case is equal to the square root of the product of the area of the grate and the area of heating surface in square feet by one hundred and forty-five one thousandths (0.145) times the cube root of the pressure in pounds above atmospheric pressure, and this product by the co-efficient for the height of the chimney.

Question. In a boiler the area of the grate is 25 square feet, that of the heating surface 625 square feet; the pressure of steam above atmospheric pressure 125 pounds per square inch, and the chimney 80 feet in height above the grate required the horse-power?

Answer. In Table 3 find height of chimney 80 feet, under which will be found its co-efficient, 1.23. Then horse-power $= 0.145 \times 1.23 \times (125)^{\frac{1}{3}} \times (25 \times 625)^{\frac{1}{2}} = 111.47.$

Pounds of Water of Temperature 32° Fahr. Evaporated Per Hour in Ordinary Steam Boilers.

The number of pounds of water evaporated per hour in ordinary steam boilers is equal to twenty-five times the square root of the product of the area of the grate, the area of the heating surface and the co-efficient for the height of the chimney.

Question. The grate surface is 16 square feet and the heating surface 400 square feet, required the number of pounds of water of temperature 32° evaporated per hour, the chimney being 60 feet in height?

Answer. By Table 3 the co-efficient for 60 feet is 1.08. Then horse-power $= 1.08 \times 25 \times (16 \times 400)^{\frac{1}{2}} = 2160$ pounds.

Pounds of Coal Consumed Per Hour on the Fire-Grate.

The pounds of coal consumed on the grate is equal to fourteen times the area of the grate in square feet multiplied by the co-efficient for the height of the chimney.

Question. The area of the grate is 16 square feet, the chimney 60 feet high, required the pounds of coal consumed?

Answer. By Table 3 the co-efficient for the chimney is 1.08. $C = 1.08 \times 14 \times 16 = 242.$ pounds of coal.

STEAM ENGINE.

The theoretical power of a steam engine is equal to the product of the area of the piston in inches, the pounds pressure of the steam per square inch and the distance traveled by the piston in one minute. The effective power in excess of back pressure, loss by friction and condensation in well constructed engines, is usually about eighty-four (.84) per cent. of the theoretical power.

The nominal power bears no fixed relation to the indicated, the theoretical or the effective power. In calculating the *nominal power*, the mean effective pressure in low pressure engines is assumed seven (7) pounds, and in high pressure engines twenty-one (21) pounds. The nominal velocity of the piston, whether in high or low pressure engines, is 128 times the cube root of the stroke in feet. The range is from 120 to 300 feet per minute. In practice, the piston not unfrequently is made to travel 900 feet and upwards a minute. Experience has determined no limit beyond which it cannot be run with advantage.

BACK PRESSURE. The back pressure of steam in the cylinder of an engine of ordinary structure is found by experience to be about four pounds to the square inch above the atmospheric back pressure, the velocity of piston being three hundred feet a minute. But in the best engines of modern construction, the back pressure is frequently below one pound per square inch, with even higher speeds of piston. It is also found that the excess of the back pressure above the atmospheric pressure varies nearly as the velocity of the piston.

Horse-Power of a Non-Condensing Steam Engine.

RULE. Multiply four times the square of the diameter of the piston in inches by the product of the number of revolutions, length of stroke in feet, and the average forward pressure of steam in pounds per square inch above atmospheric pressure, pointing off five figures as decimals.

Question. What is the effective horse-power of a non-condensing steam engine, the diameter of piston being 12 inches, length of stroke 2 feet, making 75 revolutions per minute, and the average steam pressure above atmospheric being 100 pounds.

Answer. Horse-power $= 4 \times 12 \times 12 \times 2 \times 75 \times 100 =$ 85.40000.

CUT-OFF.

The law, that in compressing a perfect gas the volumes occupied by a given quantity of it are inversly proportionate to the pressures, does not hold good with respect to saturated steam. The following Table has been computed for steam of ordinary saturation :

TABLE 4.

P. M. Randall.

Unjacketed Cylinder.			Jacketed Cylinder.		
Cut-off.	Coefficient.	Correction.	Cut-off.	Coefficient.	Correction.
	×	−		×	−
1-20	.177	12.097	1-20	.186	11.966
3-40	.244	11.113	3-40	.254	10.966
1-10	.303	10.246	1-10	.314	10.084
⅛	.356	9 467	⅛	.376	9.261
3-20	.407	8 717	3-20	.417	8.570
1-5	.496	7.409	1-5	.505	7.297
¼	.572	6.290	¼	.582	6.145
3-10	.639	5.307	3-10	.648	5.174
7-20	.697	4.454	7-20	.707	4.307
2-5	.748	3 704	2-5	.756	3.587
9-20	.797	2.984	9-20	.800	2.940
½	.833	2.455	½	.840	2.352
11-20	.869	1.926	11-20	.874	1.852
3-5	.894	1.558	3-5	.900	1.470
13-20	.923	1.132	13-20	.929	1.044
7-10	.945	0.808	7-10	.945	0.808
¾	960	0.588	¾	.960	0.588
4-5	.976	0.353	4-5	.976	0.353
17-20	.986	0.206	17-20	.986	0.206
9-10	.997	0.044	9-10	.997	0.044

Average Pressure for a given Cut-off of Stroke.

RULE. Multiply the excess of the pressure of steam above the atmospheric pressure per square inch, as it enters the cylinder, by the tabular co-efficient opposite the given cut-off, pointing off three figures as decimals, and deduct from the product the tabular correction for the given cut-off.

Question. Steam entering the cylinder at a pressure of 100 pounds to the square inch and cut-off at one-fourth ($\frac{1}{4}$) stroke. What is the mean pressure in an unjacketed cylinder? In a jacketed cylinder?

Answer. Unjacketed Cylinder. By Table 4. The co-efficient for $\frac{1}{4}$ stroke is .572; correction 6.290. Then $p. = .572 \times 100 - 6.290 = 50.910$ pounds.

Jacketed Cylinder. By Table 4. The co-efficient for $\frac{1}{4}$ stroke is .582; correction 6.145. Then $p. = .582 \times 100 - 6.145 = 52.055$ pounds.

Most Economical Point of Cut-off.

RULE. Divide the back pressure including that of the atmosphere by the total pressure.

Question. The back pressure is 3.3 pounds; that of the atmosphere 14.7 pounds, and that of the steam above atmospheric pressure 57.3 pounds. Required, the most economical cut-off.

Answer. Here the total back pressure $= 3.3 + 14.7 = 18$ pounds. Total steam pressure $= 57.3 + 14.7 = 72$ pounds. Then most economical cut-off $= 18 \div 72 = \frac{1}{4}$ stroke.

Feed-water per Horse-power.

Under the most favorable circumstances, working steam without expansion and under high pressure, for example, 130 pounds per square inch above atmospheric pressure, one-half of a cubic foot of *feed-water* an hour is required per horse-power. In ordinary practice, three-fourths of a cubic foot an hour, or .0125 of a cubic foot a minute, per horse power, should be provided. A convenient rule for finding the quantity of water required a minute per horse-power, is to divide the given number of horse-power by eighty (80).

TABLE 5.

FORMULAS AND RULES IN MENSURATION.

Hypothenuse of a right angle triangle = the square root of the sum of the squares of the base and perpendicular.

Perpendicular of an equilateral triangle = .86602 × side of the triangle.

Sum of the angles of a triangle = 180°.

An acute angle between a tangent and a chord = .5 × central angle subtended by the same chord.

An acute angle subtended by a chord, and having its vertex in the circumference of a circle = .5 × the central angle subtended by the same chord.

Circumference of a circle = 3.1416 × diameter. (nearly.)

Circumference of a circle = 22 × diameter ÷ 7. (nearly.)

Side of a square area equal that of a circle = .8863 × diameter.

Side of an inscribed square = .7071 × diameter of the circle.

Diameter of a circle = .31831 × circumference.

Diameter of an equal circle = 1.1284 × side of square.

Side of an equal cube = .806 × diameter of a sphere.

Length of a cylinder of equal diameter, also contents = .6667 × diameter of sphere.

AREAS OF

Parallelogram = base × perpendicular.

Triangle = .5 × base × height.

Trapezoid = .5 × height × sum of parallel sides.

Circle = .7854 × square of the diameter.

Sector of a circle = .5 × radius × arc of the sector.

Segment of a circle = Sector − .5 × height of triangle × chord.

Parabola = .6667 × height × base.

Ellipse = .7854 × greater diameter × less diameter.

Cycloid = 3 × area of the generating circle.

Cylinder (convex portion) = circumference × length.

Cone (right) = .5 × slant height × circumference of base.

Cube = 6 × area of one of its faces.

Sphere = diameter × circumference.

Zone, or belt of a sphere = height of segment × great circle of sphere.

SOLID CONTENTS OF

Prism (ends parallel planes) = length × area of base.

Parallelopipedon or cube = length × area of base.

Cylinder = length × area of base.

Pyramid or cone = .3333 × height × area of base.

Sphere = .16667 × diameter × circumference.

Sphere = .5236 × cube of the diameter.

Ellipsoid = .16667 × area of diametrical section × conjugate diameter.

Paraboloid = .5 × height × area of base.

Spherical cone = .16667 × diameter of sphere × height of segment × great circle.

Prismoidal Rule.

To the sum of the areas of the ends (parallel planes) add four times the area of a cross section, made by a plane midway between and parallel to the ends. Multiply this sum by one-sixth of the height or length, measured perpendicular to the planes of the ends.

The prismoidal rule is applicable in finding the solid contents of a pyramid, cone and wedge; Frustums of a pyramid, cone and wedge; Spherical and Ellipsoidal Segments and Zones, and generally to any solid bounded endwise by a pair of parallel planes and sideways by a conical, spherical, or ellipsoidal surface or by any number of planes.

Question. A telegraph pole is 12 inches by 14 inches at one end, 6 inches by 8 inches at the other end and thirty-six feet long, required, its contents in cubic feet; also its contents in board measure?

Answer. (12 + 6) ÷ 2 = 9 inches, side midway between ends. (14 + 8) ÷ 2 = 11 inches, side midway between ends. 9 × 11 × 4 = 396 sq. inches = Four times the meridian section. 12 × 14 = 168 sq. inches = area of one end. 6 × 8 = 48 square inches = area of the other end. *Then* 48 + 168 + 396 = 612 square inches = sum of areas. 612 × 36 ÷ 6 × 144 = 25.5 cubic feet, contents. 25.5 × 12 = 306. feet, board measure.

Miscellaneous.

Square foot = 144 square inches = 183.346 circular inches.
Square feet = .00695 × square inches.
Cubic feet = .00058 × cubic inches.
Cubic feet = .00045 × Cylindrical inches.
Cubic foot = 2,200. Cylindrical inches.
Cubic yards = .03704 × Cubic feet.
Cubic yards = .02909 × Cylindrical feet.
Statute miles = .00019 × Linear feet.
Statute miles = .000568 × Linear yards.
Gallons U. S. Standard = .00433 × Cubic inches.
Gallons U. S. Standard = 7.4805 × Cubic feet.
Gallons U. S. Standard = 5.8752 × Cylindrical feet.
Gallons U. S. Standard = .83312 × Imperial Gallons.
Imperial Gallons = 1.2003 × Gallons U. S. Standard.

TABLE 6.

WEIGHTS AND MEASURES—MISCELLANEOUS.

1 Cubic foot of distilled water (U. S. standard) barometer 30 inches, 39.83° Fahr. = 62.3793 lbs.

1 Cubic foot of distilled water (British standard) barometer 30 inches, 62° Fahr. = 62.321 lbs.

1 Cubic foot of sea water = 64.3 lbs.

1 Cubic foot of water distilled (U. S. standard) = 7.48052 gallons.

1 Cubic inch of water distilled (U. S. standard) = 0.0361 lbs.

1 Pound Avoirdupois = 16 ounces = 7000 grains (U. S. standard) = 27.7015 cubic inches.

1 Pound Troy = 1 Pound Apothecary = 12 ounces = 5760 grains.

1 Gallon (U. S. standard) = 231 cubic inches = 0.133681 cubic feet = 8.3389 pounds water.

1 Gallon Imperial (British standard) = 277.123 cubic inches = 0.160372 cubic feet = 10 pounds water.

1 Gallon (N. Y. statute measure) barometer 30 inches, 39.83° Fahr. = 221.184 cubic inches = 8 pounds water.

1 Bushel (U. S. standard) = 18.5 inches diameter inside,

19.5 inches diameter outside and 8 inches deep = 2150.425 cubic inches.

1 Bushel *heaped* (cone not less than 6 inches high) = 2688.041 cubic inches.

1 Bushel (N. Y. standard) = 80 pounds of water = 22.1184 cubic inches.

1 Bushel (British standard) = 8 gallons = 2216.983 cubic inches.

1 Metre = 3.2808992 feet.

1 Myriametre = 10,000 metres.

1 Square Metre = 1 centiare = 10.7643 square feet.

1 Arc = 100 square metres.

1 Cubic metre = 1 stare = 35.3166 cubic feet.

1 Gramme = 15.43234874 grains.

1 Litre = 61.0266 cubic inches = .26418 gallons U. S.

1 Chain = 100 links = 4 rods = 66 feet = 792 inches.

80 Chains = 1 mile = 5280 feet.

1 Geographical, Nautical, Knot or Sea Mile = 6,086.5 feet in longitude; and = 6,076.5 feet in latitude.

1 Statute Mile = 320 rods = 1760 yards = 5280 feet = 63360 inches.

1 League = 3 nautical miles.

1 Acre = 4 roods = 10 square chains = 160 square rods = 43560 square feet.

1 Section = 1 square mile = 640 acres.

1 Township = 36 sections = 6 miles square = 36 square miles.

1 Vara = 2.75 linear feet.

"100-Vara Lot" = 100 varas square = 75625 square feet = 1.736 1-9 acres.

"50-Vara Lot" = 50 varas square = 18906.25 square feet = .434 1-36 acres.

1 *Legua* (league) Mexican = 5000 varas linear = 13,750 feet = 2.6 1-24 miles.

1 *Legua* (of land) = 6 1801-2304 = 6.7817 square miles = 4340 5-18 acres.

1 *Square* (of roofing or flooring) = 100 square feet.

1 Cubic Yard = 27 cubic feet = 16,656 cubic inches.

1 Hundred Weight (British) = 8 stone = 112 pounds.

1 Ton (long ton) commercial = 20 hundred weight = 2240 pounds.

1 Ton (short ton) U. S. = 2000 pounds.

1 Quintal = 100 pounds.

1 Point = 1-72 inch.

1 Line = 6 points = 1-12 inch.

1 Palm = 3 inches.

1 Hand = 4 inches.

1 Span = 9 inches.

1 Fathom = 6 feet.

1 Cable-Length = 120 fathoms.

1 Cord Wood = 4 feet × 4 feet × 8 feet = 128 cubic feet.

1 Foot Board Measure = contents, 1 foot square and 1 inch thick.

12 Feet Board Measure = 1 cubic foot.

1 Sidereal Day (mean solar time) = 86,164.09 seconds.

1 Mean Solar Day = 1.00273791 sidereal days = 86,400 seconds.

1 Tropical Year = 365 days, 5 hours, 48 minutes, 49.7 seconds.

Mean Solar Time = 365.24224 mean solar days.

1 Foot-Pound = Work required to raise one pound vertically one foot.

1 Second-Foot-Pound = Work required to raise one pound vertically one foot in one second of time.

1 Minute-Foot-Pound = Work required to raise one pound vertically one foot in one minute of time.

1 Horse-Power (H. P.) = 550 second-foot-pounds = 33000 minute-foot-pounds.

Freezing point of water, barometer 30 inches = 32° above zero (0°) Fahrenheit scale.

Freezing point of water, barometer 30 inches = zero (0) centigrade scale.

Freezing point of water, barometer 30 inches = 493° below zero, absolute zero (0) scale.

Boiling point of water, barometer 30 inches = 212° above zero (0°) Fahrenheit scale.

Boiling point of water, barometer 30 inches = 100° above zero (0°) centigrade scale.

Boiling point of water, barometer 30 inches = 673° above zero (0°) absolute zero scale.

Absolute zero = 461° below the zero (0°) of the Fahrenheit scale, the point at which the nearest permanent gas becomes liquid.

1° (one degree) centigrade = 1.8° (degrees) Fahrenheit.

1 Barometric inch = column mercury, square inch base and one inch high = .491 pounds.

Atmospheric pressure per square inch = 14.7 pounds = 30 barometric inches nearly; temperature 39.83 Fahr.

1 Ounce Troy, gold 1000 fine = $20.6718.

1 Ounce Troy, gold coin U. S. 900 fine = $18.6046.

1 Pound Avoirdupois, gold coin U. S. 900 fine = $271.375.

1 Ounce Troy, silver 1000 fine = $1.29293.

1 Ounce Troy, silver coin U. S. 900 fine = $1.163636.

1 Pound Avoirdupois, silver coin U. S. 900 fine = $16.96969.

1 Dollar U. S. gold coin = 23.22 grains gold + 2.58 grains copper = 25.8 grains.

1 Dollar U. S. silver coin = 371.25 grains silver + 41.25 copper = 412.5 grains.

1 Pound Sterling = 1 sovereign = 113.001 grains gold + 10.273 grains copper = 123.274 grains total weight; fineness, 22 carat = .916 ⅔.

1 Grain gold 1000 fine = $.0430663 mint value.

1 Grain silver 1000 fine = $.0026936 mint value.

1 Gramme gold 1000 fine = $.6646142 mint value.

1 Gramme silver 1000 fine = $.0415686 mint value.

1 Cubic foot water = 773.24 cubic feet air at 39.83° Fahr.

1 Cubic foot air = .0806726 pounds = 564.7082 grains.

1 Pound of air at 39.83° = 12.387 cubic feet by volume.

1 Cubic foot hydrogen = .005042 pounds = 35.2743 grains.

Length of pendulum beating seconds at San Francisco, Latitude 37° 47′ 48″ = 3.25851 feet = 39.10212 inches.

Length of pendulum beating seconds at the Equator = 3.26058 feet = 39.12696 inches.

1 Inch Miners' Measure = that quantity of water which will flow through an inch square opening under a four inch head.

50 Miners' Inches = 1 cubic foot of water discharged per second.

MECHANICAL RULES AND TABLES.

Relations of height (distance fallen in feet), velocity (in feet per second) and time in seconds with respect to bodies falling in vacuum.

Height = .5 × velocity × time in seconds.

Height = 16.08 × square of time. (Lat. of San Francisco.)

Velocity = 32.16 × time in seconds.

Velocity = square root of 64.32 × height.

Time = velocity ÷ 32.16

Mechanical Powers.

FRICTION OMITTED.

LEVER. Power = weight × length of arm between its point of application and the fulcrum ÷ length of arm between fulcrum and the point of application of the power.

Weight = power × length of arm between its point of application and the falcrum ÷ length of arm between the fulcrum and the point of application of the weight.

WHEEL AND AXLE Power × radius of wheel = weight × radius of Axle.

INCLINED PLANE. *When the power is applied parallel to the plane.*

1st. Power = weight × height ÷ length of plane.

2nd. Resistance = weight × base ÷ length of plane.

When the power is applied parallel to the base of the plane.

1st. Power = weight × height ÷ base of plane.

2nd. Resistance = weight × length ÷ base of plane.

REMARK. The resistance is at right angles to the length of the plane.

WEDGE. Power × length = base × resistance.

PULLEY. Weight = power × number of sustaining parts of the rope.

SCREW. Power = weight × distance between the centers of the two adjacent threads ÷ 6.2832 × length of lever to which the power is applied. Or weight = 6.2832 × length of lever ÷ distance between the centers of the adjacent threads.

Leather Belts.

The working tension of a leather belt as given by General Morin is 285 pounds per square inch; the ordinary thickness of single belting, 0.16 inches; the thickness of a double belt is .32 inches. In ordinary practice a single belt running 1000 feet per minute is estimated to transmit one horse-power. The conditions to which belts are subjected are so varied that this rule is only partial in its application.

The following tables, founded on experience, taken in connection with the rules for their application, will be found very simple and reliable.

TABLE 7.

STRAINS TRANSMITTED BY BELTS OF ONE INCH WIDTH UPON PULLEY WHEN THE ARCS OF CONTACT VARY AS THE ANGLES OF

Journal Franklin Institute.

Area contact..	90°	100°	110°	120°	135°	150°	180°	210°	240°	270°
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Strain.........	32.33	34.80	37.07	39.18	42.06	44.64	49.01	52.62	55.33	52.58

TABLE 8.

Power Transmitted by Belts on Pulleys One Foot in Diameter Making One Revolution Per Minute.

ARCS OF CONTACT OF BELTS UPON PULLEYS CORRESPONDING TO THE ANGLES.

Journal Franklin Institute.

Belt 1 in. w.	90°	100°	110°	120°	125°	150°	180°	210°	240°	270°
	Ft lbs	Ft lbs	Ft lbs	Ft lbs	Ft lbs	Ft lbs	Ft lbs	Ft lbs	Ft lbs	Ft lbs
	102	109	116	123	132	140	154	165	174	181

Table to Find the Horse-Power Transmitted.

RULE. Find in Table 7 the number of pounds strain for the given arc of the pulley in contact with the belt. Multiply 303 times this number by the product of the velocity of the belt in feet and the width of the belt in inches, and point off seven figures as decimals.

To find the Horse-power Transmitted.

(SEE TABLE 8.)

RULE. Find in table 8 the number of foot pounds for the given arc of the pulley in contact with the belt. Multiply 303 times this number by the product of the diameter of the pulley in feet, revolutions per minute and width of the belt in inches, and point off seven figures as decimals.

Question. The arc of contact being 150°, the width of belt 18 inches and the velocity being 2000 feet, required, the horse-power transmitted.

Answer. By table 7. Find strain corresponding to 150° to-wit 44.64 pounds. Then H. P. $= 303 \times 44.64 \times 18 \times 2000 = 48.69$

Question. The arc of contact being 135°, the diameter of the pulley 7 feet, the number of revolutions 60 and the width of the belt 25 inches, required, the horse-power transmitted.

Answer. By table 8. Find foot pounds corresponding to 135°, to-wit 132. Then H. P. $= 303 \times 132 \times 7 \times 60 \times 25 = 41.996$.

Rectangular Beams.

The breadth, depth and length are in inches, and the tenacity or ultimate strength in pounds per square inch.

Working Conditions.

1st. Beam secured at one end and loaded at the free end. Weight = breadth × square of depth × tenacity × co-efficint ÷ 6 × length.

2nd. Secured at one end and loaded uniformly. Weight = 2 × breadth × square of depth × tenacity × co-efficient ÷ 6 × length.

3rd. Supported at both ends and loaded in the middle. Weight = 4 × breadth × square of depth × tenacity × co-efficient ÷ 6 × length.

4th. Supported at both ends and loaded uniformly. Weight = 8 × breadth × square of depth × tenacity × co-efficient ÷ 6 × length.

(For the value of the co-efficient for tenacity see Table 9.)

Cylindrical Beams.

1st. Beam secured at one end and loaded at the other. Weight = .0982 × cube of diameter × tenacity × co-officient ÷ length.

(Weights applied as in cases 2nd, 3rd and 4th of rectangular beams.)

2nd Weight = .1963 × cube of diameter × tenacity × co-efficient ÷ length..

3rd Weight = .3927 × cube of diameter × tenacity × co-efficient ÷ length.

4th Weight = .7855 × cube of diameter × tenacity × co-efficient ÷ length.

TABLE 9.

ULTIMATE STRENGTH OR TENACITY OF WOOD AND IRON.

Pitch Pine (American) 4,666 ponnds per squaro inch.

White Oak (American) 7,021 pounds per square inch.

Cast Iron, good common castings, 20,000 pounds per square inch.

Gun Iron, from gun heads, 32,000 pounds per square inch.

Wrought Iron, from 32,700 to 57,000 pounds per square inch.

Wrought Iron, average, 45,000 pounds per square inch.

In practice the factors of safety are as follows :

For wood employ, 1-10 the tabulated tenacity.

For cast-iron employ, 1-5 the tabulated tenacity.

For wrought iron employ, ¼ the tabulated tenacity.

Question. A yellow pine beam, 15 inches in breadth, 21 inches in depth and 20 feet in length, is supported at both ends and loaded in the middle. Required the weight of its working load?

Answer. Employ 3rd case under rectangular beams. By Table—Tenacity of yellow pine, 4,666; co-efficient for wood, 1-10. Working strain per square inch = 1-10 × 4,666 = 466.6. Weight = 4 × 15 × 21 × 21 × 466.6 ÷ 6 × 20 × 12 = 1234623.6 ÷ 1440 = 8573.775 pounds.

Thin Cylinders.

Question. The internal radius of a cylinder being 25 in, the fluid or steam pressure 160 pounds per square inch, and tenacity of the iron 40,000 pounds per square inch, what is the requisite thickness of the iron, taking the safety factor at $\frac{1}{4}$.

Answer. Working tension = 40,000 × $\frac{1}{4}$ = 10,000. Thickness = 25 the radius × 160 the pressure per square inch ÷ 10,000 the working tension = 4–10 inch.

Question. The thickness of the cylinder being $\frac{3}{8}$ of an inch, its radius 24 inches, and the tenacity of the iron 48,000 pounds per square inch, and the co-efficient of safety being $\frac{1}{4}$, how many pounds pressure will the cylinder carry?

Answer. Working tension = 48,000 × $\frac{1}{4}$ = 12,000. Pressure = 12,000 the working tension × $\frac{3}{8}$ thickness of iron ÷ 24 the radius = 187.5 pounds.

Thick Hollow Cylinders.

Question. The internal radius of a thick hollow cylinder being 4 inches, the working tenacity of the cylinder 6,000 pounds per square inch, and the fluid pressure 3,600 pounds per square inch, what is the external radius of the cylinder?

Answer. Sum of tenacity and fluid pressure, 6,000 + 3,600 = 9,600. Difference of tenacity and fluid pressure, 6,000 − 3,600 = 2,400. Quotient of sum and difference, 9,600 ÷ 2,400 = 4. Square root of quotient, $(4)^{\frac{1}{2}}$ = 2. External radius = 2 the quotient × 4 internal radius = 8 inches.

Question. The external radius being 8 inches, the internal radius 4 inches, and the working tension of the iron 6,000 pounds, what fluid pressure will the cylinder withstand?

Answer. Square of external radius = 8 × 8 = 64. Square of internal radius = 4 × 4 = 16. Differerence of squares, 64 − 16 = 48. Sum of squares, 64 + 16 = 80.

Fluid pressure = 6,000 working tension × 48 the difference of the squares ÷ 80 the sum of squares = 3,600 pounds.

TABLE 10.

THICKNESS OF CAST-IRON WATER PIPES.

Clarke.

Head. Feet.	Pressure pr sq. in. Pounds.	Internal Diameter of Pipe in Inches. 3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.	24 in.	30 in.	36 in.
		Thick.	Thick.	Thick.	Thick.	Thick.	Thick.	Thick.	Thick.	Thick.	Thick.	Thick.	Thick.
50	21.7	.26	.27	.28	.29	.30	.31	.32	.33	.34	.38	.41	.44
75	32.6	.27	.28	.30	.31	.33	.34	.35	.37	.39	.44	.48	.53
100	43.4	.28	.29	.31	.33	.35	.38	.39	.42	.44	.50	.56	.63
150	64.1	.30	.31	.34	.38	.41	.44	.47	.50	.53	.63	.72	.82
200	86.8	.31	.33	.37	.42	.46	.50	.51	.58	.63	.75	.87	1.00
250	108.5	.33	.35	.40	.46	.51	.56	.61	.67	.72	.88	1.03	1.20
300	130.2	.34	.37	.43	.50	.56	63	.68	.75	.81	1.00	1.19	1.38
350	151.9	.35	.39	.46	.54	.61	.69	.75	.83	.91	1.13	1.34	1.57
400	173.6	.37	.41	.50	.59	.67	.75	.83	.91	1.00	1.25	1.50	1.76
500	217.0	.41	.45	.53	.67	.77	.87	.98	1.08	1.19	1.50	1.81	2.14

REMARK. Table 10 has been computed from a business formula for the commercial minimum thickness of cast-iron pipes. The working tension of the iron is taken at 2,000 pounds per square inch nearly.

USE OF TABLE 10.

Question. The pressure is 174 pounds per square inch. Required the thickness for a pipe 30 inches diameter?

Answer. In Table 10, find in pressure column 173.6 nearest to 174. opposite which in column headed 30 inches diameter will be found 1.50 inches, the required thickness. The head corresponding is 400 feet. (See 1st. column.)

Strength of Columns or Resistance to Crushing.

Question. What is the working load of a cylindrical pine column 12 feet long and 11 inches in diameter, the safety modulus of elasticity being 156,000 pounds per square inch? (Table 11.)

Answer. Weight $= .4854 \times (11)^4$, the fourth power of the diameter in inches $\times$ 156.000, the safety modulus of elasticity in pounds $\div (144)^2$, the square of the diameter in inches $=$ 53,364 pounds.

TABLE 11.

MODULI OF ELASTICITY.

	Weisbach.
Wood—Beach, Oak, Pine, Spruce and Fir...	1,560,000 lbs
Cast-Iron....	17,000,000 lbs.
Wrought Iron....	28,400,000 lbs.

REMARK. It is customary to employ the following co-efficients for safety, viz: For wood, 1–10; for cast-iron, 1–5; for wrought iron, ¼.

HYDRAULICS.

HEAD. *Head of Water* signifies the vertical distance between the level surface of the supply and the center of gravity in the discharge opening. The term Fall is often used for that of Head.

MINERS' INCH. *The Miners' Inch of Water* (legal measure) signifies that quantity of water which will flow through an opening one inch square, in the bottom or side of a vessel, under a pressure of four inches.

EQUIVALENT. Fifty miners' inches are equal to one cubic foot of water discharged per second.

WEIGHT. A cubic foot of water at 40° Fahr. weighs 62.382 pounds, but its weight is usually taken at 62.5 pounds.

Tables and Their Uses.

The following Tables, by which anyone, however unskilled, is enabled at a glance, to solve many of the more difficult and important problems in hydraulics, have been computed from a large amount of data obtained by the most careful experiments of the ablest engineers. It is therefore with assurance that these tables are commended as the most simple and reliable of any extant.

Flow of Water Through Rectangular Orifices in Thin Vertical Partitions.

Question. The head being ten feet, and the gate opening being six inches high and one foot wide, what will be the discharge in miners' inches?

Answer. In Table 18, opposite 10 *feet* in first column, find in column headed "6 inches high, 1 foot wide," 7.62 cubic feet. Multiply this number by 50, the number of miners' inches in one cubic foot, and there results $7.62 \times 50 = 381.00$ miners' inches.

Question. The head being twenty-five feet, and the opening one and five-tenths inches high, one foot wide, how many pounds will be discharged per second?

Answer. In Table 18, opposite 25 feet in first column, find in column headed "1.5 inches high, 1 foot wide," 3.05 cubic feet. Multiply this number by 62.5, the number of pounds in a cubic foot. $3.05 \times 62.5 = 190.625$ pounds.

Question. The head being seven feet, and the opening one inch high, one foot wide, what will be the discharge in cubic feet?

Answer. In Table 18, opposite 7 feet in first column, find in column headed 3 inches high, 1 foot wide, 3.24 cubic feet. The given height 1 inch is one-third of 3 inches, the height of the opening; hence, without sensible error, we may take one-third the flow due 3 inches for that opening. 3.24 $\div 3 = 1.08$.

Flow of Water Over Weirs Per Second for Each Foot in Length of Weir.

Question. The head from still water being 8.4 inches, what is the flow for one foot in length over weir?

Answer. In the third column of Table 13 is found the given head 8.4 inches, opposite which in the fourth column find 1.96 cubic feet, the required flow.

Question. The head from still water being 2 feet 6 inches, what is the flow in miners' inches over one foot length of weir?

Answer. In the fifth column of Table 13 is found 2.6 the given head, opposite which in column sixth will be found 13.167 cubic feet flow per second. This multiplied by 50, the number of miners' inches in one cubic foot flow per second, gives 13.167 × 50 = 658.35 miners' inches.

Flow of Water in Clean Iron Pipes.

REMARKS. In the analysis of the flow of water, the total head is divided into three parts, viz: 1st, that portion of the head due to the velocity; 2nd, that portion which overcomes the resistance of entry, and 3rd, that portion which overcomes the resistances within the pipe. In long pipes, the two former portions as compared with the latter portion of the total head, are quite small. In this table the greatest velocity in any pipe is 13.445 feet per second, due to 4.2 feet the sum of the 1st and 2nd portions of the total head, while the 3rd portion of the head if 211.2 feet. The head or fall in this Table refers to the 3rd portion of the total head. This Table has been computed on the assumption that the length of any pipe is not less than one thousand times its diameter.

Question. The fall being 52 8–10 feet per mile, what will be the flow through a pipe 22 inches diameter, in cubic feet, also in miners' inches?

Answer. In Table 12, find in first column 52.8 feet, opposite which in column headed 22 inches, will be found the required quantity, viz: 21.06 cubic feet, which multiplied by 50, gives 1053 miners' inches.

Question. The diameter of the pipe being 24 inches, what fall will be required for the pipe to carry 1000 miners' inches?

Answer. In Table 12, in column headed 24 inches, find that number which multiplied by 50 will make the 1000 miners' inches given. In this case the nearest number is 20.42, opposite which in column headed fall per mile will be found 31.68 feet, the fall required.

Question. In carrying one thousand and fifty inches of water to a hydraulic mine, in a pipe twenty-seven inches diameter having a fall of 95.04 feet to the mile, what will be the effective head at the mine?

Answer. In Table 12, in column headed 27 inches, find that number which multiplied by 50 will make 1050. approximate miners' inches. In this case we have 21.13 cubic feet, opposite which in column headed fall per mile we find 18.48 feet, which is the head per mile lost in carrying the water. Subtracting this from the given fall or head, gives the effective head. Thus $95.04 - 18.48 = 76.56$ feet effective head.

Question. There being seven 5–10 gallons in a cubic foot, and 86,400 seconds in a day (twenty-four hours), the fall seven 39–100 feet per mile, how many gallons will a pipe 40 inches diameter carry per day?

Answer. In Table 12, in column headed 40 inches, and opposite 7.39 feet headed fall per mile, will be found 37.57 cubic feet flow per second. Then $37.57 \times 7.5 \times 86{,}400 = 24{,}345{,}360$ gallons.

General Rule. The velocity per second is equal to fifty times the square root of the product of the head and diameter in feet, divided by the sum of the length and fifty times the diameter of the pipe in feet.

Short Pipes. This rule applies to both long and short pipes, and is approximately accurate if the diameter does not exceed two feet.

Additional Head Necessary to Overcome the Resistance of One Circular Bend.

Question. The radius of the pipe being to the radius of the bend in the ratio of 1:5, the number of degrees in the bend being 90°, and the velocity 75 feet per second, what is the additional head required to overcome the resistance of the bend?

Answer. In Table 16, in first column headed velocity per second, find 75 feet, opposite which in column headed 1:5, 90°, is found 6.03 feet, the required head.

Question. The radius of the pipe being to the radius of the bend in the ratio of 2:5, the number of degrees in the bend being 120°, and the velocity per second 100 feet, what is the additional head required to overcome the resistance of one bend?

Answer. In Table 16, opposite 100 feet velocity, will be found in column headed 2:5, 120°, the required number, viz: 21.34 feet.

Additional Head Required to Overcome One Angular Bend.

Question. The velocity being 40 feet per second, what additional head is required to overcome the resistance of an angular bend whose angle of deflection is 90° degrees?

Answer. In Table 17, find in column headed velocity per second 40, opposite which in column headed "90°, *head*," will be found 24.45 feet, the additional head required.

Flow of Water Through Nozzles.

Question. The head being one hundred and twenty-five feet, how many cubic feet per second will a nozzle four inches in diameter discharge? How many miners' inches?

Answer. In Table 19, find in the first column the given head 125 feet, opposite which in column headed 4 inches, will be found the required quantity, viz: 7.28 cubic feet, and 7.28 × 50 = 364 *miners' inches*.

Question. Between the inlet and the nozzles of a hydraulic pipe, three feet in diameter, the distance is five miles, and the total fall two hundred and seventy-five feet. The pipe is to carry two thousand miners' inches of water, which is to be discharged through two "Little Giants," or nozzles equal in size. What will be the loss of head by the resistance in the main pipe? What will be the size of each nozzle?

Answer. In Table 12, find in column headed 36 inches, that number which multiplied by 50 will make 2000, the given number of *miners' inches*. In this case, 40.86 approximates sufficiently near, opposite which in column headed

fall per mile, is found 14.78 feet, the loss of head per mile. Multiply this by 5, the length of the pipe, and we have 14.78 × 5 = 73.9 feet, the loss by resistance in the pipe five miles long. Subtracting this from the total head, 275 - 73.9 = 201.1 feet remaining head. Again in Table 19, find 200 nearest to 201.1 feet in column headed "head," opposite which in column headed "6 inches," is found 20.64, which multiplied by 50, gives 1032 or approximately 1000 miners' inches, which each nozzle is required to discharge. Hence the nozzles are to be 6 inches in diameter each.

Relation of Clean, Slightly Rough and Very Rough Pipes With Respect to Their Carrying Capacity.

CLEAN PIPES. The Tables, as appears by the headings, have been computed for clean pipes, in other words smooth and straight.

SLIGHTLY ROUGH PIPES. When the pipe is slightly rough, multiply the tabulated number for clean pipes by the decimal .886 to determine its carrying capacity.

VERY ROUGH PIPES. If the pipe is *very rough*, multiply the tabulated number for clean pipes by the decimal .773, to determine its carrying capacity.

Relation of the Inlet Forms of Pipes With Respect to the Co-efficients of Entrance.

CO-EFFICIENTS. Of the three following forms, viz, *Bell-Mouthed*, *Square-Edged* and *Square-Edged*, projecting into the reservoir, their co-efficients will be in order .900, .836 and .734.

Flow of Water in Open Channels, Base to Perpendicular of Side Slope Being as 3:4.

Question. The dimensions of a canal being top width, 11 feet; bottom width, 5 feet; depth, 4 feet, and the fall per mile, 8 feet. Required the number of inches, miners' measure, that it will carry?

Answer. In Table 14, in column headed "fall per mile," find 8 feet, opposite which in column headed with given specifications (11, 5, 4), is found 104.8 cubic feet, the flow per second. This, multiplied by 50, the number of miners'

inches equal to one cubic foot flow per second, gives 104.8 × 50 = 5,240 miners' inches required.

Flow of Water in Open Channels, Base to Perpendicular of Side Slope Being as 2:1.

Question. Required the number of cubic feet of water that will flow in a canal whose top width is 40 feet; bottom width, 20 feet; depth, 5 feet, and whose fall is two feet per mile.

Answer. In Table 15, in column "fall per mile," find 2 feet, opposite which in column headed with the given specifications (40, 20 and 5), is found the required flow, viz: 376.1 cubic feet.

Relative Carrying Capacity of Open Channels Whose Sectional Areas are Equal Each to Each but of Different Forms

The form in which the bottom width is made equal to one of the sides, and in which the base to the perpendicular of the side slope is as 3:4. has been adopted as the standard form when the ground will admit, it being the simplest of construction.

The relative carrying capacity for Trapezoidal form, base : depth of slope : : 3 : 4; bottom width : depth : : 5 : 4. Coefficient of capacity, 1,000.

Trapezoidal form, base : depth of slope : : 1 : 1; bottom width = depth, .994.

Flume, 2 : 1, .961; semi-hexagonal, 1,008; square, .925; semi-circular, 1,056.

Question. The fall being 6 feet per mile, the sectional area of a *square flume* 8 square feet, what will be its carrying capacity per second?

Answer. In Table 14, in column of "fall per mile," find the given fall 6 feet, opposite which in column headed "sectn. 8.0 sq. ft.," is found 13.65 cubic feet. This, multiplied by the co-efficient for a sq, viz, .965, gives 13.64 × .925 = 12.63 cubic feet.

REMARK. The Tables for the flow of water in open channels have been computed upon the assumption that the canals are smooth and straight.

TABLE 12.

FLOW OF WATER IN CLEAN IRON PIPES.

P. M. Randall.

Fall Per Mile	Fall Per Rod.		Diameter.					
			½ in.	¾ in.	1 in.	1½ in.	1¾ in.	2 in.
Feet.	Ft.	In.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
21.12	0	0.792	......	......	......	......	......	.02584
26.40	0	0.990	......	......	......	......	.02014	.02924
31.68	0	1·188	......	......	......	.01460	.02270	.03274
36.96	0	1.396	......	......	......	.01583	.02426	.03492
42.24	0	1.584	......	......	.00567	.01707	.02638	.03776
47.52	0	1.782	......	......	.00617	01816	.02838	.04081
52.80	0	1.980	......	.00316	00677	.01963	.0-988	.04321
63.36	0	2.376	.00122	.00350	.00781	.02123	.03260	.04843
73.92	0	2.772	.00124	.00377	.00841	.02282	.03556	05150
84.48	0	3.168	.00135	.00411	.00886	.02466	.03706	.05456
95.04	0	3.564	.00143	.00445	.00961	.02577	03923	.05740
105 60	0	3.960	.00150	.00466	.00990	.02793	.04224	.06111
158.40	0	5.940	.00197	.00589	.01245	.03458	.05175	07399
211.20	0	7.920	.00241	.00705	.01492	.04132	.06167	.08734
264.00	0	9.900	.00279	.00798	.01666	.04577	07145	.1095
316.80	0	11.880	.00315	.00874	.01857	05043	07830	.1200
369.60	1	1.86	.00340	.00951	.01988	.05424	.08381	.1288
422.40	1	3.84	.00366	.01012	.02141	05804	.08949	.1375
475.20	1	5.82	.00389	.01086	.02283	.06191	.09400	1442
528.00	1	7.80	.00410	.01144	02424	06724	.10030	.1523
633.00	1	11.76	.00453	.01282	.02676	.07400	1110	.1634
739.20	2	3.72	.00473	.01380	.02890	.08020	.1200	.1748
844.00	2	7.68	.00524	01480	.03081	.08622	.1285	.1855
950.40	2	11.64	.00559	.01567	.03276	.09225	.1372	.1955
1056.00	3	3.60	.00589	.01656	.03458	.09692	.1450	.2047
1320.00	4	1.50	.00660	.01871	.03897	.1079	.1617	.2276
1584.00	4	11.40	.00732	.02064	.04316	.1187	.1773	.2483
2112.00	6	7.20	.00855	.02390	.04987	.1380	.2050	2833
2640.00	8	3.00	.00966	.02705	.05648	.1550	......	......
3168.00	9	10.80	.01065	.03003	.06320	......	......	......
3696.00	11	6.60	.01156	.03301	.06943	......	......	......
4224.00	13	2 40	.01248	.03572	......	......	......	......
4752.00	14	10.20	.01338	.03786	......	......	......	......
5280.00	16	5.00	.01419	......	......	......	......	......

TABLE 12. (Continued.)

FLOW OF WATER IN CLEAN IRON PIPES PER SECOND.

Fall Per Mile. Feet.	Fall Per Rod. Ft.	In.	Diameters. 3 in. Cu. ft.	4 in. Cu. ft.	6 in. Cu. ft.	8 in. Cu. ft.	10 in. Cu. ft.	11 in. Cu. ft.	12 in. Cu. ft.
5.280	0	0.198	.....						1.265
6.336	0	0.238	.....				.878	1.120	1.402
7.392	0	0.277	.....				.960	1.221	1.489
8.448	0	0.317	.....			.573	1.047	1.320	1.634
9.504	0	0.356	.....			.611	1.110	1.394	1.728
10.560	0	0.396	.....		.298	.639	1.194	1.490	1.826
11.616	0	0.436	.....		.314	.659	1.265	1.580	1.940
12.672	0	0.475	.....		.330	.703	1.325	1.653	2.026
13.728	0	0.515	.....	.1235	.346	.737	1.377	1.722	2.117
14.784	0	0.554	.....	.1298	.359	.768	1.423	1.788	2.207
15.840	0	0.594	.0630	.1335	.377	.808	1.470	1.854	2.297
18.480	0	0.684	.0692	.1465	.395	.876	1.587	1.996	2.466
21.120	0	0.792	.0749	.1562	.444	.931	1.683	2.136	2.662
26.400	0	0.990	.0839	.1771	.496	1.015	1.865	2.397	3.020
31.680	0	1.188	.0915	.1923	.548	1.157	2.059	2.636	3.310
36.960	0	1.386	.0992	.2146	.589	1.262	2.222	2.858	3.601
42.240	0	1.584	.1060	.2339	.631	1.344	2.383	3.062	3.856
47.520	0	1.782	.1119	.2460	.672	1.424	2.514	3.232	4.072
52.800	0	1.980	.1190	.2582	.721	1.496	2.662	3.419	4.305
63.360	0	2.376	.1313	.2893	.784	1.614	2.932	3.760	4.728
73.920	0	2.772	.1413	.3036	.858	1.782	3.210	4.016	5.094
84.480	0	3.168	1507	.3237	.922	1.916	3.450	4.390	5.482
95.040	0	3.564	.1590	.3412	.975	2.033	3.679	4.679	5.839
105.600	0	3.960	.1717	.3607	1.022	2.155	3.856	5.251	6.160
158.400	0	5.940	.2081	.4502	1.263	2.667	4.762	6.086	7.630
211.200	0	7.920	.2469	.5331	1.484	3.145	5.563	7.022	8.860
264.000	0	9.900	.2785	.5954	1.665	3.513	6.704	8.244	9.967
316.800	0	11.880	.3049	.6390	1.929	3.847	.....	.....	.....
369.000	1	1.860	.3331	.6967	1.976	4.196	.....	.....	.....
422.400	1	3.84	.3559	.7506	2.144	.....	.....	.....	.....
475.200	1	5.820	3816	.7960	2.274	.....	.....	.....	.....
528.000	1	7.800	.4043	.8467	2.399	.....	.....	.....	.....
633.600	1	11.760	.4440	.9270	.....	.....	.....	.....	.....
739.200	2	3.720	.4977	1.0060	.....	.....	.....	.....	.....
844.800	2	7.680	.5131	1.0810	.....	.....	.....	.....	.....
950.400	2	11.640	.5436	.....	.....	.....	.....	.....	.....
1056.000	3	3.600	.5832	.....	.....	.....	.....	.....	.....
1320.000	4	1.500	.6523	.....	.....	.....	.....	.....	.....
1584.000	4	11.400	.....	.....	.....	.....	.....	.....	.....

TABLE 12. (Continued.)

FLOW OF WATER THROUGH CLEAN PIPES PER SECOND.

Fall Per M. Feet.	Fall Per R. Ft. In.	DIAMETERS. 14 in. Cu. ft.	15 in. Cu. ft.	16 in. Cu. ft.	18 in. Cu. ft.	20 in. Cu. ft.	22 in. Cu. ft.	24 in. Cu. ft.	27 in. Cu. ft.
2.11	0 0.08	.....	.....	.....	.....	.....	.....	.....	.....
2.64	0 0.10	.....	.....	.....	.....	.....	.....	.....	8 27
3.17	0 0.12	.....	.....	.....	.....	3.61	4.61	6.10	8.37
3.70	0 0.14	.....	.....	2.25	3.10	4.07	5.25	6.64	9.09
4.22	0 0.16	1.71	2.05	2 43	3.27	4.35	5.62	7.13	9.48
4.75	0 0.18	1.83	2.19	2.59	3.49	4.68	6.01	7.56	10.26
5.28	0 0.20	1.91	2.30	2.72	3.66	4.92	6 32	7.95	10.74
5.81	0 0.22	2.02	2.43	2.88	3.88	5.15	6.62	8.34	11.45
6.34	0 0.24	2.11	2.54	3.02	4.06	5.40	6.94	8.75	11.93
6.86	0 0.26	2.18	2.65	3.18	4.23	5.62	7.24	9.14	12.54
7 39	0 0.28	2.27	2.75	3.28	4.40	5.82	7.51	9.47	12.96
7.92	0 0.30	2.35	2.84	3.39	4.61	6.05	7.78	9.80	13.49
8.45	0 0.32	2·44	2.94	3.49	4.75	6.27	8.05	10.13	13.98
8.98	0 0.34	2.54	2 98	3.62	4.90	6.48	8.36	10.57	14.41
9.50	0 0.36	2.59	3.11	3.69	5.03	6.65	8.55	10.77	14.81
10.03	0 0.38	2.67	3.21	3.81	5.17	6.92	8.85	11.10	15.21
10.56	0 0.40	2.72	3.29	3.92	5.30	7.05	9.07	11.43	15.63
11.62	0 0.44	2.88	3.47	4 12	5.63	7.42	9 55	12.05	16.44
12.67	0 0.48	3.02	3.63	4.32	5.87	7.79	10 01	12.61	17.23
13.73	0 0.51	3.15	3.79	4.51	6.18	8.14	10.48	13.23	18.01
14.78	0 0.55	3.29	3.95	4.68	6.38	8.48	10.91	13.79	18.75
15.84	0 0.59	3.42	4.11	4.87	6.64	8.77	11.29	14.25	19.50
18.48	0 0.69	3.62	4.46	5.31	7.17	9.49	12.25	15.50	21.13
21.12	0 0.79	3 99	4.78	5.67	7.65	10.16	13.12	16.62	22.62
26.40	0 0.99	4.46	5.37	6.39	8.66	11.43	14.78	18.71	25.34
31.68	0 1.19	4.91	5.91	7.02	9.54	12.59	16.20	20.42	27.74
36.96	0 1.39	5.37	6.45	7.66	10.33	13.66	17.53	22.05	29.96
42.24	0 1.59	5.77	6.90	8.16	11.09	14.66	18.78	23.61	31.99
47.52	0 1.78	6.11	7.31	8.64	11.71	15.54	19.93	25.07	33.97
52.80	0 1.98	6.44	7.70	9.10	12.37	16.47	21.06	26.42	35.89
63.36	0 2.38	7.00	8.39	9.95	13.65	17.99	23.07	29.03	39.76
73.92	0 2.77	7.60	9.15	10.87	14.75	19.49	24.68	31.49	43.22
84.48	0 3.17	8.17	9.81	11.63	15.84	21.03	26.97	33.90	46.57
95.04	0 3.56	8.93	10.47	12.43	16.90	22.45	29.70	36.18	48.06
105.60	0 3.96	9.26	11.09	13.14	17.85	23.56	31.15	38.45	.....
158.40	0 5.94	11.39	13.66	16.17	21.86	28.86	.....	.....	.....
211.20	0 7.92	13.22	15.84	18 77	.....	.....	...	.....	.....

TABLE 12. (Continued.)

FLOW OF WATER THROUGH CLEAN IRON PIPES PER SECOND.

Fall Per Mile.	Fall Per Rod.		Diameters.					
			30 in.	33 in.	36 in.	40 in.	44 in.	48 in.
Feet.	Ft.	In.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
1.06	0	0.04	......	......	10.29	13.88	18.15	22.98
1.58	0	0.06	7.78	10.21	12.70	17.00	22.22	27.89
2.11	0	0.08	8.99	11.65	14.56	19.68	25.55	32.93
2.64	0	0 10	10.24	12.92	16.35	22.08	28 87	37.00
3.17	0	0.12	10.97	13.99	18.02	24.43	31.46	40.21
3.70	0	0.14	11.90	15.14	19.76	26.27	34.47	43.67
4.22	0	0.16	12.84	16.36	20.85	28.14	37.05	46.81
4.75	0	0.18	13.48	17.58	22.30	29.80	39.01	49 06
5.28	0	0.20	14.21	18.74	23.47	31.46	41.06	52.15
5.81	0	0.22	15.05	19.54	24.91	33.25	42.09	54.95
6.34	0	0.24	15.81	20.28	26.12	34.68	44.97	57.36
6.86	0	0.26	16.47	21.29	27.20	36.21	46.77	60.07
7.39	0	0.28	17.18	22.20	28.24	37.57	48.83	62.02
7.92	0	0.30	17.94	23.01	29.19	39.18	50.62	64.47
8.45	0	0.32	18.58	23.76	30.29	40.54	52.46	66.53
8.98	0	0.34	19.21	24 47	31.42	41.88	54.04	68.50
9.50	0	0.36	19.66	25.22	32.48	43.07	55.48	70.62
10.03	0	0.38	20.32	26.14	33.40	44.28	57 01	72.75
10.56	0	0.40	20.79	26.94	34.49	45.20	58.85	74.44
11.62	0	0.44	21.80	28 27	36.15	48.12	61.71	78.29
12.67	0	0.48	22.83	29.02	37.74	50.48	64.35	81.68
13.73	0	0.51	23.93	31.06	39.40	52.67	66.87	85.20
14.78	0	0.55	24.86	32.28	40.86	55.04	69.57	88.46
15.84	0	0.59	25.87	33.62	42.28	56.33	72.32	91.73
18.48	0	0 69	27.96	36.17	45.95	61.09	77 95	100.40
21.12	0	0.79	29.84	38.57	48.83	65.41	83.60	105.89
26.40	0	0.99	33.55	43.12	54.89	73.09	93.37	119.34
31.68	0	1.19	36.79	47.40	59.95	80.32	103.28	130.88
36.96	0	1.39	39.66	51.35	65.17	86.70	111.74	142.09
42.24	0	1.59	42.39	54.91	69.80	92.58	119.93	153.94
47.52	0	1.78	45.23	58.20	74.33	98.00	128.26	....
52.80	0	1.98	47.71	61.62	78.46	103.99	....	....
63.33	0	2.38	52.91	68.00	82.84	....	....	....
73.92	0	2.77	57.65	73.95	......	....	....	....

TABLE 12. (Continued.)

FLOW OF WATER THROUGH CLEAN IRON PIPES PER SECOND.

Fall Per Mile. Feet.	Fall Per Rod. Ft.	In.	Diameters. 54 in. Cu. ft.	60 in. Cu. ft.	72 in. Cu. ft.	84 in. Cu. ft.	96 in. Cu. ft.
.53	0	0.02	21.96	29.77	46.99	75.43	107.77
1.06	0	0.04	31.70	38.19	57.65	104.61	152.45
1.58	0	0.06	38.53	52.09	82.53	126.18	188.45
2.11	0	0.08	45.12	59.04	95.99	145.43	218.75
2.64	0	0.10	50.23	67.56	109.42	162.75	245.30
3.17	0	0.12	55 51	74.32	121.58	177.03	267.41
3.70	0	0.14	60.21	80.51	132.04	192.04	290 53
4.22	0	0.16	63.61	86.30	139.96	207.81	310.89
4.75	0	0.18	67.20	91.99	148.72	222.44	324.20
5.28	0	0.20	72.37	96.98	157.77	235.13	350.45
5.81	0	0.22	75.71	102.39	165.97	253.34	366.19
6.34	0	0.24	79.13	107.31	173.04	264.77	382.02
6.86	0	0.26	82.54	115.53	179.26	275.16	397.85
7.39	0	0 28	85.90	116.53	187.46	287.67	414.70
7.92	0	0.30	89.52	119.68	193.93	296.37	427.76
8 45	0	0.32	92.47	123.70	200.18	307.87	443.09
8.98	0	0.34	95 35	127.63	206.40	316.15	457.42
9.50	0	0.36	97.65	131.26	212.05	326.73	470.49
10.03	0	0.38	100.19	134.79	217.71	335.79	481.53
10.56	0	0.40	103.82	138.84	225.21	348.25	496.37
11.62	0	0.44	108.78	145.98	235.52	364.92	522.76
12.67	0	0.48	113.47	152.56	246.41	389.09	547.38
13.73	0	0.51	118.48	158.65	256.17	394.43	570.01
14.78	0	0.55	123.10	164.54	267 19	408.36	592.13
15.84	0	0.59	128.19	170.43	277.88	423.36	612.00
18.48	0	0.69	138.92	183.98	299.72	482.99	....
21.12	0	0.79	147.91	197.52	320.74	....	....
26.40	0	0.99	165.80	221.95	358.52	....	....
31.68	0	1.19	182.42	244.26	....	....	....
36.96	0	1.39	190.01	....	....	....	....

TABLE 13.

FLOW OF WATER OVER WEIRS PER SECOND FOR EACH FOOT IN LENGTH OF WEIR.

P. M. Randall.

Head from Still Water. Ft.	In.	Flow per S. 1 ft. in lgt. Cu. ft.	Head from Still water. Ft.	In.	Flow per S. 1 ft. in lgt. Cu. ft.	Head from Still water. Ft.	In.	Flow per S. 1 ft. in lgt. Cu. ft.
0	0.48	.026	0	5.52	1.039	1	2.4	4.390
0	0.60	.037	0	5.76	1.107	1	3.6	4.951
0	0.72	.048	0	6.00	1.177	1	4.8	5.531
0	0.84	.060	0	6.24	1.248	1	6.0	6.134
0	0.96	.074	0	6.48	1.321	1	7.2	6.756
0	1.08	.088	0	6.72	1.395	1	8.4	7.399
0	1.20	.104	0	6.96	1.472	1	9.6	8.052
0	1.32	.120	0	7.20	1.551	1	10.8	8.732
0	1.44	.137	0	7.44	1.629	2	0.0	9.430
0	1.56	.154	0	7.68	1.708	2	1.2	10.146
0	1.68	.172	0	7.92	1.789	2	2.4	10.869
0	1.80	.191	0	8.16	1.871	2	3.6	11.619
0	1.92	.210	0	8.40	1.960	2	4.8	12.385
0	2.04	.230	0	8.64	2.038	2	6.0	13.167
0	2.16	.251	0	8.88	2.124	2	7.2	13.965
0	2.28	.273	0	9.12	2.212	2	8.4	14.778
0	2.40	.295	0	9.36	2.300	2	9.6	15.607
0	2.64	.341	0	9.60	2.388	2	10.8	16.450
0	2.88	.388	0	9.84	2.479	3	0.0	17.309
0	3.12	.438	0	10.08	2.570	3	1.2	18.181
0	3.36	.489	0	10.32	2.662	3	2.9	19.068
0	3.60	.545	0	10.56	2.756	3	3.6	19.969
0	3.84	.593	0	10.80	2.850	3	4.8	20.795
0	4.08	.657	0	11.04	2.946	3	6.0	21.719
0	4.32	.716	0	11.28	3.043	3	7.2	22.657
0	4.56	.776	0	11.52	3.141	3	8.4	23.607
0	4.80	.838	0	11.76	3.240	3	9.6	24.571
0	5.04	.902	1	0.00	3.339	3	10.8	25.547
0	5.28	.972	1	1.20	3.852	4	0.0	26.536

TABLE 14.

FLOW OF WATER IN OPEN CHANNELS—BASE TO PERPENDICULAR OF THE SIDE SLOPES BEING AS 3 : 4.

P. M. Randall.

Fall per Mile. Feet.	Fall per Rod. Inches.	T 2.2 ft B 1.0 ft D .8 ft Section 1.28 sq ft. Cu. ft.	T 3.3 ft B 1.5 ft D 1.2 ft Section 2.88 sq ft. Cu. ft.	T 4.4 ft B 2.0 ft D 1.6 ft Section 5.12 sq ft. Cu. ft.	T 5.5 ft B 2.5 ft D 2.0 ft Section 8.0 sq ft. Cu. ft.	T 6.6 ft B 3.0 ft D 2.4 ft Section 11.52 sq ft. Cu. ft.	T 7.7 ft B 3.5 ft D 2.8 ft Section 15.68 sq ft. Cu. ft.	T 8.8 ft B 4.0 ft D 3.2 ft Section 20.48 sq ft. Cu. ft.
1	.0375	.45	1 33	2.67	5.57	9.05	13.46	20.26
2	.0750	.63	1.88	3.87	7.88	12.80	19.04	28.64
3	.1125	.77	2.30	4.74	9.65	15.67	23.32	35.08
4	.1500	.89	2.65	5.47	11.14	18.52	26.93	40.51
5	.1875	1.00	2.97	6.12	12.46	20.24	30.11	45.30
6	.2250	1.09	3.25	6.70	13.65	22.17	32.98	49.62
7	.2625	1.18	3.42	7.24	14 74	23.94	35.63	53.58
8	.3000	1.26	3 75	7.73	15.75	25 60	38.08	57.28
9	.3375	1.34	3 98	8.21	16.71	27.15	40.39	60.76
10	.3750	1.41	4.19	8.65	17.61	28.62	42.57	64.05
11	.4125	1.48	4.40	9.07	18.47	30.02	44.65	67.18
12	.4500	1.54	4.60	9 48	19.30	31.35	46.64	70.65
13	.4875	1.61	4 78	9.86	20.08	32.63	48.54	73.03
14	.5250	1.67	4.96	10.24	20.84	33.87	50.38	75.79
15	.5625	1.73	5.14	10.60	21.57	35.05	52.14	78.44
16	.6000	1.78	5.31	10.94	22.27	36.20	53.86	81.02
17	.6375	1.84	5.47	11.28	22.96	37.31	55.51	83.51
18	.6750	1.89	5.63	11.60	23.63	38.39	57.11	85 93
19	.7125	1.94	5.78	11.92	24.28	39.44	58.58	88.29
20	.7500	1.99	5.93	12.23	24.91	40.47	60.21	90.58
21	.7875	2.04	6.08	12.54	25.53	41.47	61.70	92.82
22	.8250	2 09	6.22	12.83	26.12	42.45	63.15	95.00
23	.8625	2.14	6.36	13.12	26.71	43.40	64.57	97.15
24	.9000	2.18	6.50	13.40	27.29	44.34	65.95	99.23
25	.9375	2.23	6.63	13.68	27.98	45.24	67.32	101.28

In Table 14, T signifies top width; B, bottom width; D, depth.

TABLE 14. (Continued.)

FLOW OF WATER IN OPEN CHANNELS—BASE TO PERPENDICULAR OF SIDE SLOPES BEING AS 3 : 4.

Fall per Mile. Feet.	Fall per Rod. Inches.	T 9.9 ft B 4.5 ft D 3.6 ft Section 25 92 sq ft. Cu. ft.	T 11. ft B 5. ft D 4. ft Section 32. sq ft. Cu. ft.	T 13.2 ft B 6.0 ft D 4.8 ft Section 46.09 sq ft. Cu. ft.	T 16.4 ft B 7.0 ft D 5.6 ft Section 62.72 sq ft. Cu. ft.	T 17.6 ft B 8 0 ft D 6.4 ft Section 81.92 sq ft. Cu. ft.	T 19.8 ft B 9.0 ft D 7.2 ft Section 103.68 sq ft. Cu. ft.	T 22. ft B 10. ft D 8. ft Section 128. sq ft. Cu. ft.
1	.0375	28.04	37.1	58.4	96.5	138.3	189.2	261.2
2	.0750	39.67	52.4	82.7	136.4	195.7	267.6	369.4
3	.1125	48.59	64.2	101.4	167.1	239.6	327.7	451 3
4	.1500	56.10	74.1	117.1	192.9	276.7	378.4	522.3
5	.1875	62.71	82.9	130.9	215.7	309.3	423.1	584.0
6	.2250	68.70	90.8	143.4	236.3	338.8	463.5	639.8
7	.2625	74.19	98.1	154.8	255.3	366.0	500.5	691.0
8	.3000	79.53	104.8	165.5	272.9	391.2	535.1	738 7
9	.3375	84.14	111.1	175.6	289.4	415.0	567.6	783.5
10	.3750	88.68	117.1	185.1	305.0	437.4	598.2	825.9
11	.4125	93.02	122.9	194.1	319.9	458.7	613.2	866.2
12	.4500	97.15	128.4	202.8	334.2	479.1	655.4	925.6
13	.4875	101.13	133.6	211.1	347.8	498.7	682.1	941.7
14	.5250	104.94	138.7	219.0	360.9	517.5	707.8	977.2
15	.5625	108.63	143.5	226.6	373.6	535.7	732.8	1011.5
16	.6000	112.18	148.2	234.1	385.9	553.3	756.7	1044.7
17	.6375	115.64	152.4	241.3	397.8	570.3	780.1	1076.9
18	.6750	118.99	157.2	248.3	409.3	586.9	802.7	1108.1
19	.7125	122.26	161 5	255.1	420.5	601.5	824.8	1138.4
20	.7500	125.43	165.7	261.7	431.4	618.5	846.1	1168.0
21	.7875	128.53	169.8	268.2	442 0	633.9	867.0	1196.8
22	.8250	131.55	173.8	274 5	452.5	648.8	887.4	1225.0
23	.8625	134.51	177.7	280.7	462.9	663.4	907.4	1252.6
24	.9000	137.40	181.5	286.7	472.6	677.7	926.9	1279.5
25	.9375	140.24	185.3	292.6	482.3	691.6	946.0	1306.0

In Table 14, T signifies top width; B, bottom width; D, depth.

TABLE 15.

FLOW OF WATER IN OPEN CHANNELS—BASE TO PERPENDICULAR OF THE SIDE SLOPES BEING AS 2 : 1.

P. M. Randall.

Fall per Mile. Feet.	Fall per Rod. Inches.	T 6. ft B 2. ft D 1. ft Section 4. sq ft. Cu. ft.	T 9. ft B 3. ft D 1.5 ft Section 9. sq ft. Cu. ft.	T 12. ft B 4. ft D 2. ft Section 16. sq ft. Cu. ft.	T 16. ft B 6. ft D 2.5 ft Section 27.5 sq ft. Cu. ft.	T 22. ft B 10. ft D 3. ft Section 48. sq ft. Cu. ft.	T 28. ft B 12. ft D 4. ft Section 30. sq ft. Cu. ft.	T 40. ft B 20. ft D 5. ft Section 150. sq ft. Cu. ft.
.5	.01875	1.27	3.85	8.63	18.11	38.79	78.2	188.1
.6667	.0250	1.46	4.44	9.96	20.91	44.79	90.3	217.2
.8333	.03125	1.63	4.96	11.14	23.38	50.08	101.0	242.8
1.	.0375	1.79	5.44	12.20	25.61	54.86	110.6	266.0
1 25	.046875	2.00	6.08	13.64	28.68	61.32	123.7	297.4
1.5	.05625	2.19	6.67	14.96	21.34	67.26	135.7	326.1
1.75	.065625	2.37	7.19	16.14	33.88	72.57	146.4	351.8
2.	.0750	2.53	7.69	17.26	36.22	77.58	156.5	376.1
2.25	.084375	2.68	8.16	18.30	38.42	82.29	165.9	399.0
2.5	.09375	2.83	8.60	19.29	40.50	86.72	174.9	420.6
3.	.1125	3.10	9.42	21.14	44.36	95.00	191.6	460.7
3.5	.13125	3.35	10.17	22.83	47.91	102.6	207.0	497.6
4.	.1500	3.58	10.87	24.41	51.22	109.7	221.3	531.9
4.5	.16875	3.79	11.54	25.88	54.33	116.3	234.7	564.2
5.	.1875	4.00	12.16	27.29	57.27	122.7	247.4	594.8
6.	.2250	4.38	13.31	29.89	62.74	134.4	271.0	651.5
7.	.2625	4.73	14.39	32.29	67.79	145.1	292.7	703.6
8.	.3000	5.06	15.38	34.52	72.43	155.2	312.9	752.2
9.	.3375	5.37	16.31	36.61	76.83	164.6	331.9	797.9
10.	.3750	5.66	17.19	38.59	80.99	173.5	349.9	841.1
11.	.4125	5.93	18.03	40.47	84.94	181.9	366.9	882.1
12.	.4500	6.20	18.74	42.27	88.72	190.1	383.2	921.3

In Table 15, T signifies top width; B, bottom width; D, depth.

TABLE 16.

ADDITIONAL HEAD REQUIRED TO OVERCOME THE RESISTANCE OF ONE CIRCULAR BEND.

P. M. Randall.

Velocity per Sec. Feet.	Ratio of Radius of Pipe to Radius of Bend. 1 : 5 30° Head. Feet.	1 : 5 60° Head. Feet.	1 : 5 90° Head. Feet.	1 : 5 120° Head. Feet.	1 : 5 180° Head. Feet.	2 : 5 30° Head. Feet.	2 : 5 60° Head. Feet.	2 : 5 90° Head. Feet.	2 : 5 120° Head. Feet.	2 . 5 180° Head. Feet.
1.	.0004	.0007	.0011	.0014	.0022	.0005	.001	.002	.002	.005
2.	.0014	.0029	.0043	.0058	.0086	.0021	.004	.006	.008	.013
3.	.0032	.0064	.0096	.0128	.0192	.0048	.010	.014	.020	.029
4.	.0057	.0114	0171	.0228	.0342	.0085	.017	.025	.034	.051
5.	.0089	.0179	.0268	.0358	.0536	.0133	.027	.040	.054	.080
6.	.0129	.0257	.0386	.0514	.0772	.0192	.038	.058	.076	.115
7.	.0175	.0350	.0525	.0700	.1050	.0261	.052	.078	.104	.157
8.	.0229	.0457	.0686	.0914	.1372	.0341	.068	.102	.136	.205
10.	.0357	.0714	.1072	.1428	.2144	.0533	.107	.160	.214	.320
15.	.0804	.1607	.2411	.3214	.4822	.1200	.240	.360	.480	.720
20.	.1429	.2858	.4287	.5716	.8574	.2130	.426	.639	.852	1.28
25.	.2232	4464	.6696	.8928	1.34	.3333	.667	1.00	1.33	2.00
30.	.3214	.6428	.9642	1.29	1.93	.4798	.960	1.44	1.92	2.88
40.	.5714	1.14	1.71	2.28	3.42	.8530	1.71	2.56	3.42	5.12
50.	.8927	1.79	2.68	3.58	5 36	1.33	2.66	3.99	5.32	7.98
75.	2.01	4.02	6.03	8.04	12.06	3.00	6.00	9.00	12.00	18.00
100.	3.57	7.14	10.71	14.28	21.42	5.33	10.67	15.99	21.34	31.98
150.	8.04	16.07	24.11	32.14	48.22	12.00	24.00	36.00	48.00	72.00
200.	14.29	28.58	42.87	57.16	85.74	21.32	42.64	63.96	127.92	127.92
300.	32.14	64.28	96.42	128.56	192.84	47.98	95.96	143.94	287.88	287.88

TABLE 17.

ADDITIONAL HEAD REQUIRED TO OVERCOME THE RESISTANCE OF ONE ANGULAR BEND.

P. M. Randall.

Velocity Per Second. Feet.	Angles of Deflection.					
	15° Head. Feet.	30° Head. Feet.	40° Head. Feet.	60° Head. Feet.	90° Head. Feet.	120° Head. Feet.
1	.0002	.0005	.002	.006	.015	.029
2	.0010	.0019	.009	.023	.061	.116
3	.0022	.0042	.019	.051	.138	.260
4	.004	.008	.035	.090	.245	.462
5	.006	.012	.054	.141	.382	.723
6	.009	.017	.078	.204	.550	1.04
7	.012	.023	.106	.277	.749	1.42
8	.016	.030	.138	.362	.978	1.85
10	.025	.047	.216	.565	1.53	2.89
15	.056	.105	.486	1.27	3.44	6.50
20	.099	.186	.863	2.26	4.85	11.56
25	.155	.291	1.35	4.45	9.55	18 06
30	.224	.419	1.94	5.09	13.75	26.01
40	.398	.745	3.45	9.04	24.45	46.23
50	.621	1.17	5.40	14.13	38.20	73.93
75	1.40	2.62	12.14	31.79	85.95	162.5
100	2.48	4.66	21.58	56.52	152.8	289.0
150	5.59	10.48	48.57	127.2	343.7	650.2
200	9.94	18.63	86.32	226.1	611.1	1156.
300	22.36	41.92	194.20	508.7	1092.	2601.

TABLE 18.

FLOW OF WATER THROUGH RECTANGULAR ORIFICES IN THIN VERTICAL PARTITIONS.

P. M. Randall.

Head upon center of orifice. feet.	Velocity per second. feet.	Breadth and Height of Orifice. 1 ft. High 1 ft. Wide Cu.ft	H.P.	9 in. High 1 ft. Wide Cu.ft	H.P.	6 in. High 1 ft. Wide Cu.ft	H.P.	3 in. High 1 ft. Wide Cu.ft	H.P.	1.5in.high 1 ft. Wide Cu.ft	H.P.
0.2	3.58	.....	.....	.....	.....	.....	.....	.....	.....	0.28	.0064
.3	4.40	.....	.....	.....	.....	.....	.....	0.69	.022	.34	.010
.4	5.07	.....	.....	.....	.....	1.56	.071	.80	.036	.40	.018
.5	5.67	.....	.....	2.57	.146	1.74	.099	.89	.051	.45	.026
.6	6.22	3.72	.253	2.83	193	1.91	.130	.98	.066	.49	.033
.7	6·72	4.02	.317	3.06	.249	2.07	.165	1.06	.082	.53	.041
.8	6.38	4.31	.392	3.27	.297	2.21	.201	1.14	.104	.57	.052
.9	7.62	4.57	.467	3.48	.356	2.35	.240	1.20	.122	.60	.061
1.0	8.025	4.87	.554	3.67	.417	2.48	.281	1.26	.144	.63	.072
1.25	8.99	5.29	.751	4.02	.571	2.71	.385	1.39	.197	.69	.098
1.50	9.83	5·92	1.01	4.50	.767	3.03	.517	1.55	.259	.77	.129
1.75	10.59	6.40	1.27	4.86	.967	3.27	.650	1.67	.326	.83	.163
2.00	11.35	6.85	1.56	5.20	1.18	3.50	.795	1.79	.398	.89	.199
2.25	12.00	7.27	1.86	5.51	1.41	3.71	.949	1.89	.475	.95	.237
2.50	12.68	7.67	2.18	5.81	1.65	3.91	1.11	1.99	.565	1.00	.283
2.75	13.32	8.05	2.53	6.09	1.86	4.10	1.28	2.09	.654	1.04	.327
3.00	13.90	8.41	2.87	6.36	2.17	4.27	1.46	2.18	.743	1·09	.371
3.50	15.01	9.08	3.61	6.86	2.73	4.61	1.83	2.35	.935	1·17	.467
4.00	16.05	9.97	4.54	7.32	3.33	4.92	2.24	2.50	1.14	1·25	.568
4.50	17.02	10.29	5.26	7.75	3.96	5.21	2.66	2.65	1.36	1·32	.678
5.00	17.95	10.84	6.16	8.16	4.64	5.49	3.12	2.78	1.58	1·39	.781
6.	19.66	11.84	8.08	8.91	6.08	5.98	4.08	3.03	2.07	1·51	1.03
7.	21.23	12.76	10.14	9.61	7.64	6.43	5.12	3.24	2.58	1·62	1.29
8.	22.71	13.64	12.40	10.25	9.32	6.84	6.22	3.45	3.14	1·71	1.50
9.	24.70	14.47	14.80	10.86	11.11	7.25	7.42	3.64	3.72	1·83	1.82
10.	25.38	15.25	17.34	11.44	13.00	7.62	8.66	3.83	4.34	1·92	2.18
15.	31.08	18.68	31.85	14.01	23.88	9.34	15.93	4.[illegible]9	8.00	2·36	4.02
20.	35.89	21.50	49.05	16.18	36.78	10.80	24.55	5.42	12.29	2·72	6.15
25.	40.13	24.12	68.52	18.10	51.42	12.08	34.32	6 06	17·22	3·05	8.67
30.	43.95	26 43	90.10	19.84	67.64	13.47	45.92	6.64	22.64	3.35	11.42
35.	47.47	28.55	113.6	21.44	85.27	14.31	56.96	7.18	28.56	3.62	14.40
40.	50.75	30.53	138.8	22.94	104.3	15.32	69.64	7.68	34.91	3.79	17.23
45.	53.83	32.39	165.6	24.35	124.5	16.26	83.14	8.16	41.73	4.12	21.02
50.	56.75	34.15	194.0	25.68	145.8	17.16	97.50	8.61	48.92	4.35	24.72

TABLE 19.

FLOW OF WATER THROUGH NOZZLES — QUANTITY AND HORSE-POWER.

P. M. Randall.

Head. Feet.	Velocity pr sec. Feet.	50 M inch 1 cu ft H. P.	100 M inch 2 cu ft H. P.	Diameters of Nozzles. 1 inch.		1.5 inches.		2 inches.		2.5 inches.	
				cu ft	H P	cu ft	H P	cu ft	H P	cu ft	H P
1	8.025	.106	.212	.041	.0046	.093	.010	.164	.018	.255	.029
1.5	9.83	.158	.316	.050	.0085	.111	.019	.200	.034	.312	.053
2	11.35	.211	.422	.058	.013	.130	.029	.232	.052	.369	.082
2.5	12.68	.264	.528	.064	.018	.145	.041	.256	.072	.402	.114
3	13.90	.317	.634	.061	.024	.159	.054	.284	.096	.440	.150
3.5	15.01	.370	.740	.076	.030	.171	.068	.304	.120	.475	.189
4	16.05	.421	.842	.081	.037	.183	.083	.324	.148	.507	.231
4 5	17.02	.474	.948	.086	.044	.194	.099	.344	.176	.540	.275
5	17.95	.528	1.06	.091	.051	.205	.113	.364	.204	.567	.315
6	19.66	.634	1.27	.100	.068	.224	.153	.400	.272	.622	.425
7	21.23	.739	1.48	.108	.086	.242	.193	.432	.344	.672	.535
7:5	21.98	·702	1.58	.111	.095	.250	.214	.444	.380	.697	.595
10	25.38	1.06	2.12	.129	.146	.290	.329	.516	.584	.805	.915
12.5	28.37	1.32	2.64	.144	.204	.324	.460	576	.816	.897	1 28
15	31.08	1.59	3.18	.158	.269	.355	.505	.632	1.08	.985	1 68
17.5	33.57	1.85	3.70	.170	.339	.383	.782	.680	1.36	1.06	2.11
20	35.89	2.11	4.22	.182	.414	.410	.931	.728	1.66	1.14	2.58
22.5	38.07	2.38	4.76	.193	.494	.435	1.11	.772	1.98	1.21	3.08
25	40.13	2.64	5.28	.204	.578	.458	1.30	.816	2.31	1.27	3.61
27.5	42.08	2.90	5 80	.213	.667	.480	1.50	.852	2,67	1.33	4 17
30	43.95	3.02	6.04	.228	.760	.513	1.71	.912	3.04	1.42	4.75
32.5	45.75	3.34	6.68	.232	.857	.522	1.93	.928	3.43	1.45	5.35
35	47.47	3.69	7.38	.241	.958	.542	2.15	.964	3.83	1.51	5.98
40	50.75	4.22	8.44	·257	1.17	.579	2.63	1.03	4.68	1.61	7.31
45	53.83	4.75	9.50	.273	1.40	.614	3.14	1.09	5.60	1.71	8.23
50	56.75	5.28	10.56	.288	1.64	.648	3.68	1.15	6.56	1.79	10.22
60	62.16	6.34	12.68	.385	2.15	.709	4.84	1.26	8.60	1.97	13.43
70	67.14	7.39	14.78	.341	2.71	.766	6.10	1 36	10.84	2.13	16.93
80	71.78	8.46	16.90	.364	3.31	.819	7.45	1.46	13.24	2.27	20.69
90	76.13	9.53	19.06	.386	3.95	.864	8.88	1.54	15.80	2.44	24.68
100	80.25	10.56	21.12	.407	4.63	.916	10.41	1.63	18.52	2,54	28.90
125	89.72	13.21	26.42	.456	6.47	1.02	14.55	1.82	25.88	2.84	40.40
150	9[illegible].28	15.85	31.70	.499	8.50	1.12	19.12	2.00	34.00	3.11	53.12
175	106.1	18.50	37.00	.539	10.70	1.21	24.07	2.16	42.80	3.36	66.86
200	113.5	21.14	42.28	.576	13.1	1.29	29.43	2.30	52.4	3.59	81.75
250	127.1	26.42	52.84	.644	18.3	1.45	41.13	2.58	73.2	4.02	114.2
300	139.0	31.70	63.40	.705	24.0	1 59	54.07	2.82	96.0	4.40	150.2
350	150.1	37.08	74.16	.762	30.3	1.71	68 15	3.05	121.2	4.76	189.3
400	160.5	42.27	84.54	.814	37.0	1.83	83.25	3.26	148.0	5.09	231.2
450	170.2	47.64	95.28	.864	44.2	1.94	99.34	3.46	176 8	5.40	276.0
500	179.4	52.84	105.7	.910	51.7	2.05	116.5	3.64	206.8	5.69	323.2
550	188.2	58.22	116.4	.955	59.7	2.10	134.2	3.82	238.8	5.96	372.7
600	196.6	63.41	126.8	.999	68.0	2.23	152.9	3.99	272.0	6.23	475.0
700	212.3	73.98	148.0	1.06	85.7	2.46	192.8	4.36	342 8	6.79	535.5
800	226.9	84.55	169.1	1.15	104.7	2.58	235.5	4.60	418.8	7.19	654.0
900	240.7	95.14	190.3	1.22	124.9	2.75	281.0	4.88	499.6	7.63	780.5
1000	253.8	105.6	211·2	1.29	146.2	2.89	329.0	5.16	584.8	8.04	914.0

TABLE 19. (Continued.)

FLOW OF WATER THROUGH NOZZLES — QUANTITY AND HORSE-POWER.

Head. Feet.	Velocity pr sec. Feet.	150 M inch 3 cu ft H. P.	200 M inch 4 cu ft H. P.	Diameters of Nozzles. 3 inches.		3.5 inches.		4 inches.		4.5 inches.	
				cu ft	H P	cu ft	H P	cu ft	H P	cu ft	H P
1	8.025	.308	.424	.372	.040	.50	.056	.656	.072	.81	.090
1.5	9.8[illegible]	.474	.632	.444	.076	.61	.105	.800	.136	1.00	.171
2	11.35	.638	.814	.520	.116	.70	.160	.928	.208	1.17	.260
2.5	12.68	.792	1.06	.58[illegible]	.164	.79	.224	1.02	.288	1.30	.370
3	13.90	.951	1.27	.636	.216	.86	.295	1.14	.384	1.43	.485
3 5	15.01	1.110	1.48	.681	.272	.94	.370	1.22	.480	1.54	.612
4	16.05	1.26	1.68	.742	.332	1.02	.452	1.30	.592	1.64	.742
4 5	17.02	1.42	1.90	.776	.396	1.06	.540	1.38	.704	1.74	.815
5	17.95	1.58	2.12	.820	.452	1.11	.6 0	1.46	.816	1.84	1.02
6	19.66	1.90	2.54	.896	.[illegible]12	1.22	.833	1.60	1.09	2.01	1.38
7	21.23	2.22	2.96	.968	.772	1.32	1.05	1.73	1.38	2.18	1.74
7:5	21.98	2.38	3.16	1 00	.856	1.36	1.16	1.78	1.52	2.25	1.92
10	25.38	3 18	4.24	1.16	1.32	1.57	1.79	2.16	2 34	2.61	2.97
12.5	28.37	3.96	5.28	1.30	1.81	1.76	2.50	2.30	3.46	2.92	4.14
15	31.08	4.77	6.36	1.42	2.42	1.93	3.29	2.53	4.32	3.19	5.44
17.5	33.57	5.55	7.40	1.53	3.13	2.[illegible]8	4.20	2.72	5 44	3.44	7.04
20	35.89	6.33	8.44	1.64	3.72	2.23	5.07	2.91	6.64	3.69	8 37
22.5	38.07	7.14	9.52	1.74	4.41	2.36	6.05	3 09	7.92	3.91	9 99
25	40.13	7 92	10.56	1.83	5.20	2.54	7.08	3.26	9.24	4.12	11.70
27.5	42.[illegible]8	8.70	11.60	1.92	6.00	2.61	8.17	3.41	10.68	4.32	13 50
30	43.95	9.06	12.08	2 05	6.81	2.79	9.31	3.65	12.16	4.61	15.39
32.5	45.75	10.02	13.36	2.09	7.72	2.84	10.50	3.71	13.72	4.70	17.37
35	47.45	11.07	14.76	2.17	8.60	2.95	11.71	3.83	15.32	4 88	19.35
40	50.7[illegible]	12.66	16.88	2.32	10.52	3.15	14 33	4.12	18.72	5.22	23.[illegible]7
45	53.83	14 25	19.00	2.40	12.56	3.24	17.10	4.36	22 40	5.54	28 25
50	56.75	15.84	21.12	2.59	14.72	3.52	20 03	4.60	26.24	5.83	32 12
60	62.10	19.02	25.36	2.84	19.36	3.86	26.32	5.04	34.40	6.39	43.55
70	67.14	22.17	29.56	3.06	24.40	4 17	33.17	5.42	43.36	6.84	54.90
80	71.7[illegible]	25.36	33 86	3.28	29.80	4.40	40.55	5.81	52.96	7.38	67.05
90	76.13	28.59	38 12	3.46	35.52	4.73	43.37	6.16	6[illegible].20	7.78	79.[illegible]2
100	80.25	31.68	42.24	3 66	41.64	4.98	56.67	6.52	74.08	8.23	[illegible]3.70
125	89.72	39.63	52.84	4.08	58.20	5.57	79.2[illegible]	7.28	103.5	9.18	130.9
150	9[illegible].28	47.55	63.40	4.48	76.48	6.10	104.10	8.00	136.0	10.08	172 1
175	106.1	55.50	74.00	4.84	96.28	6.60	131.07	8.[illegible]4	171.2	10.89	216.6
200	113.5	[illegible]3.42	84.56	5.10	117.7	7.05	160.22	9.20	219.6	11.61	261.7
250	127.1	[illegible]9.26	105 7	5 8[illegible]	[illegible]64.5	7.88	223 92	10.32	292.8	13.05	370.2
300	139.0	95.10	126.8	6.30	216 3	8.63	294.3	11.28	381 0	14.31	483.9
350	150.1	111.2	148.3	6 84	272.6	9.33	371.2	12.20	484 8	15.39	613 2
400	160.[illegible]	126.8	169.1	7.3	323.0	9.97	453.2	13.04	592.0	16.47	749.2
450	170.[illegible]	142.9	190.6	7.76	397.4	10.58	541.0	13.84	707.2	17.46	894.2
500	179.4	158.5	211.4	8.20	466.0	11.15	627.0	14.56	827.2	18.45	1048.
550	188.2	174.7	232.8	8.40	536.8	11.69	731 0	15.28	955.2	18.90	12[illegible]8.
600	196.[illegible]	190.2	253.6	8 92	611 [illegible]	12.21	832.7	15.96	1083.0	20.07	1[illegible]76.
700	212.3	221.9	296.0	9 84	771.2	13.31	1051.	17.44	1371.2	22.14	1735.
800	22[illegible].9	253.6	338.2	10.32	942.0	14.10	1282.	18 40	1675.2	23.22	2119.
900	240.7	285.4	380.6	11 00	1124	14.9	1530.	19.52	1998 4	24.75	2529.
1000	253.8	316.8	422.4	11.56	1316.	15.76	1791.	20.64	2330.2	26.00	2961.

TABLE 19. (Continued.)

FLOW OF WATER THROUGH NOZZLES — QUANTITY AND HORSE-POWER.

Head. Feet.	Velocity pr sec. Feet.	300 M inch 6 cu ft H. P.	400 M inch 8 cu ft H. P.	Diameters of Nozzles. 5 inches.		5.5 inches.		6 inches.		7 inches.	
				cu ft	H P	cu ft	H P	cu ft	H P	cu ft	H P
1	8.025	.616	.8 8	1.02	.116	1.23	.140	1.49	.160	1.99	.226
1.5	9.83	.948	1.26	1.25	.212	1.51	.257	1.78	.304	2.44	.420
2	11.35	1.27	1.69	1.44	.327	1.74	.395	2.08	.464	2.82	.641
2.5	12.68	1.58	2.11	1.61	.457	1.95	.553	2.32	.656	3.15	.896
3	13.90	1.90	2.54	1.76	.601	2.13	.727	2.54	.864	3.45	1.18
3.5	15 01	2.22	2.96	1·90	.757	2.31	.916	2.74	1.09	3.78	1.48
4	16.05	2.53	3.37	2.03	.925	2.46	1.12	2.97	1.33	4.09	1.84
4.5	17.02	2.84	3.79	2.16	1.10	2.51	1.33	3.10	1.58	4.23	2.16
5	17.95	3.18	4.24	2.27	1.26	2.75	1.53	3.28	1.81	4.46	2.48
6	19.66	3 81	5.08	2.49	1.70	3.02	2 05	3.58	2.45	4.88	3.33
7	21.23	4.44	5.92	2.69	2.14	3.26	2.59	3 87	3.09	5.28	4.20
7.5	21.98	4·74	6.32	2.79	2.38	3.42	2 87	4.00	3.42	5.46	4.66
10	25.38	6.36	8.48	3·22	3.66	3.89	4.42	4.64	5.28	6.30	7.16
12.5	28.37	7.92	10 56	3.59	5.11	4.35	6.18	5.20	7.36	7.05	10.02
15	31 08	9.54	12.72	3.94	6.72	4.76	8.13	5.68	8.08	7.72	13.17
17.5	33.57	11.10	14 80	4.26	8.46	5.15	10.24	6.12	12.52	8.34	16.80
20	35.89	12.66	16.88	4.55	10.34	5.50	12.51	6.56	14.88	8.92	20.28
22.5	38.07	14.28	19.04	4.83	12.34	5 84	14.93	6.96	17.76	9.46	24.20
25	40.13	15.84	21.12	5.09	14.45	6.16	17.49	7.32	20.80	10.15	28.33
27.5	42.08	17.40	23.20	5.34	16.67	6.46	20.18	7.68	24.00	10.46	32.68
30	43.95	18.12	24.16	5.70	19.00	6.90	22.99	8.20	27.36	11.18	37.25
32.5	45.75	20.04	26.72	5.80	21.42	7.02	25.92	8.36	30.88	11.37	41.99
35	47.47	22.14	29.52	6.02	23.94	7.28	28.97	8.68	23.40	11.80	46.84
40	50.75	25.32	33.76	6.44	29.25	7.78	35 39	9 28	42.08	12.61	57.33
45	53.83	29.50	38.00	6.82	34.90	8.26	42.23	9.84	50.24	13.38	68.40
50	56.75	31.68	42.24	7.19	40.87	8.70	49.46	10.36	58.88	14.10	80.11
60	62.16	38.04	50.72	7.88	53.72	9.54	65.01	11.36	77.44	15.44	105.8
70	67.14	44.34	59.12	8.51	67.72	10.30	81.95	12.24	97.60	16.69	132.7
80	71.78	50.74	67.64	9.10	82.76	11.01	100.1	13.12	119.2	17.84	162.2
90	76.13	57.18	76.24	9.65	98.72	11.58	119.5	13.84	142.1	18.92	193.5
100	80.25	63.36	84.48	10.17	115.6	12.31	139.9	14.64	166.6	19.94	226.7
125	89.72	79.26	95.68	11.38	161.6	13.76	195.0	16.32	232.8	22.30	316.8
150	98.28	95.10	126.8	12.46	212 5	15.08	257.0	17.92	305.9	24.42	416.4
175	106.1	111.0	148.0	13.46	267.5	15.29	313.7	19.36	385.1	26.89	524.3
200	113.5	126.8	169.1	14.34	327.0	17.51	395.7	20 64	470.8	28.20	640.9
250	127.1	158.5	211.4	16.09	457.0	19.47	553.0	23.20	658.0	31.54	895.7
300	139.0	190.2	253.6	17.62	601.0	21.33	726.9	25.44	865.2	34.54	1177.
350	150.1	222.5	296.6	19.04	757.2	22.04	916.3	27.36	1090.4	37.32	1485.
400	160.5	253.6	338.2	20.35	925.0	24.62	1179.	29.28	1332.	39.89	1813.
450	170.2	285.8	381.1	21.59	1104.	26.12	1335.	31.04	1590.	42.81	2164.
500	179.4	317.1	422.8	22 75	1293.	27.54	1565	32.80	1864.	44.00	2508.
550	188.2	349.2	465.6	23.86	1491.	28.88	1805.	33.60	2147.	46.78	2923.
600	196.6	380.4	507.2	24.93	1699.	30 16	2056.	35 08	2446.	48.86	3331.
700	212.3	444.0	592.0	27.18	2142.	32.88	2591.	39.36	3085.	53.26	4203.
800	226.9	507.3	676.4	28.77	2616.	34.92	3166.	41 28	3768.	56.40	5129.
900	240.7	570.9	761.2	30.52	3122.	36.94	3778.	44.00	4496.	59.83	6120.
1000	253.8	633.6	844.8	32.17	3656.	38.93	4424.	46.24	5264.	63.06	7166.

TABLE 19. (Continued.)

FLOW OF WATER THROUGH NOZZLES — QUANTITY AND HORSE-POWER.

Head. Feet.	Velocity pr sec. Fee	500 Min inch 10 cft H. P.	1000 Min inch 20 cft H. P.	Diameters of Nozzles. 8 inches. cu ft	H P	9 inches. cu ft	H P	10 inches. cu ft	H P	12 inches. cu ft	H P
1	8.025	1.06	2.12	2.62	.288	3.35	.360	4.07	.46	5.96	.904
1.5	9.83	1.58	3.16	3.20	.544	3.99	.684	4.99	.85	7.12	1.68
2	11.35	2.11	4.22	3.71	.832	4.68	1.04	5.76	1.3	8.32	2.56
2.5	12.68	2 64	5.28	4.08	1.15	5.22	1.48	6.44	1.83	9.28	3 58
3	13.90	3.17	6.34	4.56	1.54	5.72	1.94	7.05	2.40	10.16	4.72
3.5	15.01	3.70	7.40	4.88	1.92	6.16	2.45	7.62	3.03	10.96	5.92
4	16.05	4.21	8 42	5.20	2.37	6.58	2.99	8.14	3.70	11 88	7.24
4 5	17.02	4.74	9.48	5.52	2.81	6.98	3.26	8.64	4.42	12.40	8 64
5	17.95	5.28	10·6	5.84	3.26	7.28	4.07	9.10	5.05	13.12	9.92
6	19.66	6.34	12·7	6.40	4.36	8.06	5.51	9.97	6.80	14.32	13.32
7	21.23	7.39	14·8	6.94	5.52	8.71	6.95	10.77	8 57	15.48	16.80
7:5	21.98	7.92	15 8	7.12	6.08	9.00	7.70	11.14	9.50	16.00	18.64
10	25.38	10.6	21·2	8.64	9.36	10.44	11.88	12.87	14.63	18.56	28.64
12.5	28.37	13.2	26·4	9.20	13.84	11.70	16.56	14.39	20.44	20.80	40.08
15	31.08	15.9	31·8	10.12	17.28	12.78	21.78	15.76	26.87	22.72	52.68
17.5	33.57	18.5	37 0	10.88	21.76	13.77	28.17	17.03	33.86	24.48	67.20
20	35.89	21.1	42·2	11.64	26.56	14.76	33 48	18.20	41 37	26.24	81.12
22.5	38.07	23.8	47·6	12.36	31.68	15.66	39.96	19.31	49.37	27.84	96.80
25	40.13	26.4	52·8	13.04	36.96	16.47	46.80	20.35	57.82	29.28	113.3
27.5	42.08	29.0	58·0	13.64	42.72	17.28	54.00	21.34	66.70	30.72	130.7
30	43 95	30.2	60·4	14.60	48.64	18.45	61.56	22 81	76.01	32.80	149.0
32.5	45.75	33.4	66·8	14.84	54.88	18 81	69.48	23.20	85.70	33.44	168.0
35	47.47	36.9	73·8	15.44	61.28	19.53	77.40	24.08	95.78	34.72	187.4
40	50.75	42.2	84·4	16.48	74 88	20.88	94.68	25.74	117.0	37.12	229.3
45	53.83	47.5	95.0	17.44	89.60	22.14	113.0	27.30	139.6	39.36	273.6
50	56.75	52.8	105.6	18.40	105.0	23.31	128.5	28.78	163.5	41.44	320.4
60	62.16	63.4	126.8	20.16	137.6	25.56	174.2	31 53	214.9	45.44	421.2
70	67.14	73.9	147.8	21.68	173.4	27.54	219.6	34.06	270.9	48.96	530.8
80	71.78	84.6	169.0	23.36	211.8	29 52	268.2	36.41	331.0	52.48	648.8
90	76.13	95.3	190.6	24.64	252.8	31.14	319.7	38.61	394.9	55.36	774.0
100	80.25	105.6	211.2	26.08	296.3	32.94	374.8	40.70	462.5	58.56	906.8
125	89.72	132.1	264.2	29.12	414.0	36.72	523.8	45 51	646.5	65.28	1267.
150	98.28	158.5	317.0	32.00	554.0	40.32	688.3	49.85	849.8	71.68	1666.
175	106.1	185.0	370.0	34.56	684.8	43.56	866.5	53.85	1070	77.44	2097.
200	113.5	211.4	422.8	36.80	878.4	46.44	1059.	57.56	1308.	82.56	2564.
250	127.1	264.2	528.4	41.28	1171.	52.20	1481.	64.36	1828.	92.80	3583.
300	139.0	317.0	634.0	45.12	1536.	57.24	1947.	70.50	2403.	101.76	4708.
350	150.1	370.8	741.6	48.80	1949.	61.56	2453.	76.15	3029.	109.4	5940.
400	160.5	422.7	845.4	52.16	2368.	65.88	2997.	81.41	3700.	117.1	7252.
450	170.2	476.4	952.8	55.36	2829.	69.84	3577.	86.35	4415.	124.2	8656.
500	179.4	528.4	1057.	58.24	3409.	73.80	4194.	91.02	5172	131.2	10032
550	188.2	582.2	1164.	61.12	3821.	75.60	4831.	95.46	5966.	134.4	11692.
600	196.6	634.1	1268.	63.84	4352.	80.28	5504.	99.71	6798.	142.7	13324.
700	212.3	739.8	1480.	69.76	5485.	88.56	6941.	108.7	8567.	157.4	16812
800	226.9	845.5	1691.	73.60	6701.	92.8	8478.	115.1	1046[illegible].	165.1	20516.
900	240.7	951.4	1903.	78 08	7994.	99.00	10116.	122 1	12489.	176.0	24480.
1000	253.8	1056.	2112.	82.56	9357.	104.0	11844.	128.7	14624.	185.0	28664

WATER WHEELS.

TABLE 20.

VELOCITIES OF VARIOUS WATER WHEELS WITH RESPECT TO THE SUPPLY VELOCITIES AND THEIR EFFICIENCIES.

Names of Wheels.	Wheel Velocities With Respect to the Supply.	Efficiency Best Results.	Efficiency Average Results.
Undershot wheel.	At mid. of floats .43 per c.	40 per cent.	27 to 30 per c.
Poncelet Un'sht "	" " 55 per c.	65 " "	50 to 55 "
Paddle wheel.....	" " 33 to 40 per c.	38 " "	27 to 30 "
Breast wheel......	At mid. of floats 50 per c.	93 ? " "	70 to 75 "
Overshot wheel...	" " " " 50 per c.	80 " "	70 to 75 "
Tub wheel.......	" " " " 53 per c.	40 " "	15 to 30 "
Whitelaw wheel..	At circum. 1.00 per c.	76 " "	66 "
Fourneyron wheel	At inner circum. 56 per c.	79 " "	
Boyden wheel....	At inner circum. 56 per c.	88 " "	
Fontaine wheel...	At mean circum. 55 per c.		57 to 70 "
Jonval wheel.....	At exter. circum. 70 per c.	72 " "	
Swain wheel......	At circum. 76 per c.	84 " "	68 to 78 "
Girard wheel......	At mean circum. 50 per c.	87 " "	75 to 80 "
Hurdy Gurdy ...	" " " 50 per c.		60 to 80 "
Tangential wheels	" " " 50 per c.		60 to 80 "

Water wheels are of two classes, *Horizontal* and *Vertical*. The *horizontal* class embraces the Undershot, with radial floats or buckets; the Paddle wheel, with radial floats, employed in open currents; the Poncelet, with curved floats, an improved Undershot; the Breast wheel, which receives the water at a level a little below that of the axis, and the Overshot, which receives the water just below the top. The *vertical* class embraces the Tub wheel; the Whitelaw Water Mill, which acts on the principle of Barker's Centrifugal Mill; the various Turbines—namely, the Outward-flow Turbines, as the Fourneyron and the Boyden; the Downward-flow Turbines, as the Fontaine and Jonval; the Inward-flow Turbine or Vortex wheel, as the Swaine; and the Tangential wheels, as the Girard Turbine and the "Hurdy Gurdy."

The Hurdy Gurdy is especially adapted to *high heads*, and is one of the most simple and efficient wheels in use.

As determined by experience, the proper velocities of the various wheels with respect to the supply velocities, also their efficiencies, will be found in Table 20.

Water Wheels — Effective Power Of.

Question. The head being 15 feet, the gate opening 9 inches high and 1 foot wide, what effective horse-power will the stream render on an Undershot water wheel?

Answer. In Table 18, find head 15 feet, opposite which under heading "9 inches high, 1 foot wide," is found 23.88 horse-power. Again Table 20 shows the efficiency of an Undershot water wheel to be from 27 to 30 per cent. Taking 30 per cent. then 23.88 × .30 = 7.16 horse-power sought.

Question. A nozzle 2½ inches diameter, under a head of 200 feet, supplies a good Hurdy Gurdy wheel with water, what horse-power will the wheel render?

Answer. In Table 19, find the given head 200 feet, opposite which under 2.5 inches (diameter of nozzle) is found 81.75 horse-power. Again Table 20 shows the efficiency of a Hurdy Gurdy wheel to be from 60 to 80 per cent. Taking 70 per cent. then 81.75 × .70 = 57.23 horse-power rendered.

Water Wheels — Diameter Determined From Velocity of Flow of Water.

Question. It is required that a Hurdy Gurdy wheel shall make 250 revolutions per minute, the head being 350 feet, required the diameter of the wheel that shall be the most efficient?

Answer. In Table 19, find head 350 feet, opposite which under velocity per second is found 150.1 feet. Table 20 shows the proper velocity of the Hurdy Gurdy to be 50 per cent. of the supply velocity. Then 150.1 × .50 = 75.05 feet velocity per second at the mean circumference, and 75.05 × 60 = 4503. feet velocity per minute; 4503 ÷ 250 = 18.012 mean circumference of wheel; 18.012 × 7 ÷ 22 = 5.731 feet diameter of wheel.

Question. What horse-power is developed by 200 miners' inches on an Overshot water wheel 40 feet diameter?

Answer. In Table 19, find head 40 feet, opposite which in column headed "200 miners' inches" is found 16.88 horse-power. Table 20 shows the efficiency of an Overshot wheel to be from 70 to 75 per cent. say 75 per cent. Then 16.88 × .75 = 12.66 horse-power sought.

TABLE 21.

DIAMETERS IN INCHES OF WROUGHT IRON SHAFTS—NUMBER OF REVOLUTIONS PER MINUTE.

Nystrom.

H. P.	10 in.	20 in.	30 in.	40 in.	50 in.	60 in.	80 in.	100 in.	150 in.	200 in.	300 in.	500 in.	1000 in.
5	3.97	3.15	2.75	2.50	2.33	2.18	1.99	1.96	1.71	1.56	1.36	1.15	0.91
10	5.00	3.98	3.47	3.15	2.92	2.75	2.50	2.22	2.03	1.85	1.61	1.36	1.08
20	6.30	5.00	4.37	3.97	3.69	3.47	3.15	2.92	2.56	2.33	2.03	1.71	1.36
30	7.21	5.72	5.00	4.54	4.22	3.97	3.61	3.34	2.92	2.66	2.33	1.96	1.55
40	7.94	6.30	5.50	5.00	4.65	4.37	3.98	3.68	3.22	2.92	2.56	2.15	1.71
50	8.55	6.79	5.93	5.58	5.00	4.71	4.28	3.97	3.47	3.15	2.75	2.33	1.84
60	9.08	7.21	6.30	5.72	5.32	5.08	4.55	4.21	3.68	3.35	2.93	2.47	1.96
70	9.57	7.59	6.64	6.03	5.60	5.27	4.79	4.44	3.88	3.53	3.06	2.60	2.06
80	10.00	7.94	6.94	6.30	5.85	5.51	5.00	4.64	4.05	3.63	3.22	2.71	2.15
100	10.80	8.55	7.47	6.78	6.31	5.93	5.39	5.00	4.37	3.97	3.47	2.92	2.31
140	12.0	9.57	8.37	7.59	7.06	6.64	6.03	5.59	4.89	4.44	3.88	3.27	2.59
200	13.6	10.80	9.42	8.55	7.94	7.48	6.79	6.30	5.50	5.00	4.37	3.68	2.92
300	15.5	12.3	10.8	9.80	9.10	8.57	7.77	7.21	6.30	5.73	5.00	4.11	3.35
400	17.1	13.6	11.9	10.8	10.0	9.42	8.55	7.94	6.93	6.30	5.50	4.64	3.68
500	18.4	14.6	12.8	11.6	10.8	10.1	9.21	8.55	7.46	6.79	5.93	5.00	3.97
600	19.6	15.5	13.5	12.3	11.5	10.8	9.79	9.08	7.92	7.21	6.30	5.32	4.22
800	21.5	17.1	15.0	13.6	12.6	11.9	10.8	10.0	8.74	7.94	6.93	5.85	4.64
1000	23.3	18.5	16.1	14.6	13.6	12.8	11.6	10.8	9.41	8.55	7.47	6.30	5.00
1500	26.6	21.1	18.5	16.7	15.5	14.6	13.3	12.3	10.7	9.79	8.55	7.21	5.72
2000	29.3	23.5	20.3	18.4	17.1	16.1	14.6	13.5	11.8	10.8	9.41	7.94	6.30
2500	31.5	25.0	21.9	19.8	18.4	17.3	15.8	14.6	12.8	11.6	10.2	8.55	6.73
3000	33.5	26.6	23.3	21.1	19.6	18.4	16.7	15.5	13.5	12.3	10.8	9.09	7.41
4000	36.8	29.3	25.6	23.3	21.6	20.3	18.5	17.1	15.0	13.6	11.8	10.0	7.94
5000	39.6	31.5	27.2	25.0	23.3	21.9	19.9	18.4	16.1	14.6	12.8	11.8	8.55

FLY WHEELS.

TABLE 22.

SHOWING THE HORSE-POWER DUE THE DIAMETER, WEIGHT OF RIM AND REVOLUTIONS.

P. M. Randall.

Dia.	Weight.		No.	Revolutions Per Minute.							
Feet.	Rim. Pounds.	Total Pounds.	Segment.	5 H. P.	10 H. P.	20 H. P.	30 H. P.	40 H. P.	60 H. P.	80 H. P.	100 H. P.
5	800	1,000	16 in. for Belt	.0006	.0023	.009	.021	.037	.084	.147	.23
6	960	1,200	14 " " "	.0011	.0043	.017	.039	.069	.156	.275	.43
7	1,520	1,900	14 " " "	.0023	.0091	.036	.082	.146	.338	.582	.91
8	3,600	4,500	20 " " "	.0071	.0282	.113	.254	.451	1.015	1.805	2.82
9	2,550	3,180	15 " " "	.0064	.0256	.102	.230	.410	.920	1.638	2.52
5	820	1,024	Whole oval.	.0006	.0024	.010	.022	.038	.088	.154	.26
5	770	960	" "	.0005	.0022	.008	.020	.035	.080	.141	.24
6	880	1,100	" Square.	.0009	.0037	.015	.033	.059	.132	.237	.32
7	1,200	1,500	6 "	.0017	.0070	.028	.063	.112	.252	.448	.77
8	1,440	1,800	Whole "	.0026	.0103	.042	.093	.165	.372	.659	1.00
10	2,000	2,500	6 "	.0058	.0233	.093	.210	.373	.840	1.49	2.33
12	2,800	3,500	6 "	.0119	.0477	.191	.389	.763	1.56	3.05	4.73
16	4,000	5,000	6 "	.0310	.1239	.496	1.11	1.98	4.44	7.93	12.37
16	6,400	8,000	8 "	.0496	.1983	.793	1.79	3.17	7.16	12.69	19.89
18	7,000	8,700	8 "	.0692	.2770	1.11	2.40	4.13	10.00	17.73	27.73
18	7,500	9,000	8 "	.0749	.2996	1.20	2.70	4.80	10.80	19.17	29.90
18	8,000	10,000	8 "	.0794	.3176	1.27	2.85	5.08	11.40	20.34	31.76
18	9,500	12,000	8 "	.0950	.3799	1.52	3.42	6.08	13.68	24.32	37.
20	20,000	25,000	Depth 1.25 ft.	.22	.91	3.6	8.2	14.5	32.8	58.0	90
20	20,000	25,000	3.5 ft wide Blt	.25	1.0	4.0	9.1	16.2	36.4	64.8	101.2
25	40,000	50,000	Depth 1.0 ft.	.75	3.0	11.9	26.7	47.6	107.0	190.3	297.0
30	50,000	62,500	Depth 1.25 ft.	1.6	6.4	25.6	57.6	102.4	230.4	409.6	640.0
35	80,000	100,000	Depth 1.25 ft.	2.9	11.8	47.0	105.8	188.2	423.4	752.6	1176.0
40	100,000	125,000	Depth 1.5 ft.	4.8	19.3	77.3	174.0	309.3	696.0	1237.6	1933.0

Question. The diameter of the Fly-wheel being 40 feet, the weight of the rim 100,000 pounds, the number of revolutions 60 per minute, how many horses-power are stored up in the wheel to be given out in one minute when the motor ceases to act?

Answer. In Table 22, in column headed diameter, find 40 feet, opposite which in column headed "weight, rim," find 100,000 pounds; then opposite which in column headed 60 revolutions per minute will be found 686, the horse-power sought.

Question. The diameter of the Fly-wheel being 30 feet, the weight of the rim 50,000 pounds, the number of revolutions 10 per minute, how many horse-power are stored up in the wheel to be given out in one-fourth of a minute when the motor shall cease to act?

Answer. In Table 22, in column headed diameter, find 30 feet, opposite which in column headed "weight, rim," find 50,000 pounds, then opposite which in column headed 10 will be found 6.4, the number of horse-power to be given out in one minute. Multiply this number by 4, since the work is to be accomplished in one-fourth of a minute, thus $6.4 \times 4 =$ 25.6 horses-power sought.

Question. The diameter of our Fly-wheel is eighteen feet, the weight of its rim 9,600 pounds, the number of its revolutions 80 per minute, the engine is working 200 horse-power, how many revolutions will the Fly-wheel make after the steam is shut off?

Answer. In Table 22, in column headed diameter, find 18 feet, opposite which in column headed "rim," find 9,600, and opposite which in column headed 80 (the given number of revolutions) find 24.32 horse-power per minute. Now 200 (the work of engine) is to 24.32 (the work of Fly-wheel) as 80 (revolutions of Fly-wheel) is to the number sought. Thus $24.32 \times 80 \div 200 = 9.728$ revolutions.

Question. The diameter of a Fly-wheel being 40 feet, weight of rim 100,000 pounds, making 100 revolutions per minute, what is the centrifugal force in its effort to disrupt the wheel?

Answer. In Table 22, in column headed diameter, find 40 feet, opposite which in column headed rim find 100,000 pounds, and opposite which in column headed 100 find 1933. horse-power. Now the product of the horse-power and 66,000 divided by the radius of the wheel will give the Centrifugal force. Thus 1933. × 66,000 ÷ 20 = 1,159,800 pounds.

SHEARING AND PUNCHING.

Question. What force can a wrought iron rivet 1½ inches diameter withstand with safety, the safety strength being 8,333 pounds per square inch, viz, 1–6 of the ultimate strength?

Answer. Here 1½ inches = 1.5 inches. Force = .7854 × $(1.5)^2$ × 8,333 = 14,726 pounds.

Question. The thickness of the sheet iron being ¾ of an inch, what force is required to punch a hole 1½ inches through it, its ultimate strength of shearing being 50,000 pounds per square inch?

¾ inches = .75; and 1½ inches = 1.5.

Answer. Force = 3.1416 × 1.5 × .75 × 50,000 = 176,715 pounds.

TABLE.

MODULI OF ULTIMATE STRENGTH OF SHEARING.

Cast-iron	32,300 lbs. per square inch.
Wrought iron	50,000 " " " "
Fine cast-steel	92,400 " " " "

Safety fraction usually 1–6.

TABLE 23.

CO-EFFICIENTS OF FRICTION OF MOTION.

Weisbach.

	Dry.	Water.	Hog Lard.	Greasy.
Wood upon wood......	0.36	0.25	0.07	0.12
Metal upon metal....	0.18	0.31	0.09	0.13
Wood upon metal....	0.42	0.24	0.07	0.14

HUMID TESTS OF ORES.

(FROM RANDALL'S QUARTZ OPERATORS' HAND BOOK.)

In making tests by the wet mode, the ore is powdered, roasted (usually), digested or boiled in acid and filtered or strained. The solution is then tested with reagents. Its behavior determines its kind. Most metallic substances are soluble in nitric acid. Gold, platinum and horn silver, (chloride of silver) are exceptions. Gold and platinum require *aqua-regia* (composed of equal parts by volume of nitric acid and muriatic acid,) for their solution. Horn silver is soluble in ammonia; also in cyanide of potassium in solution. A solution is said to be neutral when none of the properties either of the acid or base are perceptable; or when it can no farther act upon a fresh supply of the original substance being tested. It is said to be acid while it retains power of farther action.

Silver (oxide).

Either potash or ammonia in solution, introduced into the silver solution produces a light brown precipitate, usually soluble in ammonia.

Copperas, green vitriol. (Proto sulphate of iron.) Produces a white precipitate consisting of metallic silver.

Common salt in solution, also muriatic acid produce a white curdy precipitate which becomes violet and finally black. It is soluble in ammonia.

This precipitate (chloride of silver), is readily revived to to metalic silver by bringing it in contact with clean iron plate.

Zinc plate precipitates silver from its solutions in the metalic state.

Gold (oxide).

Ammonia added to a solution of gold, (gold dissolved in *aqua regia*), produces a yellow precipitate, (aurate of ammonia or fulminating gold.)

Copperas, green vitriol, (proto sulphate of iron), produces a brown precipitate of metallic gold. From its solution oxalic acid precipitates metallic gold. From its solution zinc-plate precipitates metallic gold in the form of a brown coating.

REMARK. The wet mode is seldom resorted to by the miner. Having thoroughly powdered the ore, he washes it in a horn or pan, sometimes employing a little quicksilver for amalgamating. In which case the amalgam is usually retorted in a paper conically rolled, and ends twisted or turned down.

Copper (oxide).

Potash produces from a copper solution—a voluminous blue precipitate which by boiling becomes black.

Ammonia, added in small quantities to the copper solution, produces a green basic salt, which desolves in excess forming a fine blue solution. In this solution potash produces in the cold a blue precipitate which, by boiling, becomes black.

A clean iron plate introduced into the blue solution specified, becomes covered with a deposit of metallic copper, while the blue solution becomes colorless on yielding up all of its copper.

Mercury (oxide).

Potash, added to the solution of mercury, produces a yellow precipitate insoluble in excess.

Ferro-cyanide of potassium produces a white precipitate which becomes blue.

Iodide of potassium produces a cinnabar red precipitate, soluble in excess. It crystalizes out of a hot solution in splendid crimson spangles.

Iron (protoxide).

Potash and ammonia produce a floculent precipitate, nearly white at first, but becomes colored by exposure to the air.

Ferrocyanide of Potassium produces a white precipitate if the air be excluded, but by exposure to air, or by contact with nitric acid, it forms Prussian blue.

Zinc (oxide).

In neutral solutions of zinc, potash and ammonia give a white jelly-like precipitate, soluble in an excess of the precipitants.

Ferro-cyanide of potassium produces a similar precipitate which is insoluble in muriatic acid.

Cobalt (oxide).

Potash produces a blue precipitate, insoluble in excess of the precipitant, but soluble in carbonate of ammonia. The precipitate becomes green by exposure to the air, and dingy-red when boiled.

Alkaline carbonates produce a red precipitate which upon being boiled becomes blue.

Ferro-cyanide of potassium gives a green precipitate which gradually turns gray.

Manganese (oxide).

Ferro-cyanide of potassium produces a pale-red precipitate, soluble in free acids.

Ferro-cyanide of potassium gives a brown precipitate, insoluble in free acids.

Lead (oxide).

Potash and ammonia added to a solution of lead, produce white precipitates, soluble in a great excess of potash, but insoluble in ammonia.

Muriatic acid produces a heavy white precipitate, soluble in boiling water, out of which it separates on cooling in brilliant crystals. This precipitate is soluble in potash.

Sulphuric acid produces a white precipitate, soluble in a solution of potash.

Bismuth (oxide).

Potash and ammonia produce a white precipitate, insoluble in excess.

Ferro-cyanide of potassium produces a white precipitate, insoluble in muriatic acid.

Ferro-cyanide of potassium produces a light yellow precipitate, soluble in muriatic acid.

Tin (oxide).

Potash and ammonia produce a white precipitate, soluble in excess of potash, but not in ammonia.

By repose, and more rapidly when boiled, the solution is decomposed. Metallic tin, peroxide of tin, and potash being formed.

A plate of metallic zinc precipitates tin in small grayish white metallic spangles.

Chloride of gold produces a purple precipitate (purple of Cassius), insoluble in muriatic acid.

Platinum (peroxide).

Potash, in a platinum solution (*aqua regia* the solvent), produces a yellow crystalline precipitate. The addition of muriatic acid favors its formation. It is insoluble in acids, but dissolves with the aid of heat in potash.

Subnitrate of mercury produces a yellowish-red precipitate.

Tellurious Acid.

The caustic alkalies and their carbonates produce a white precipitate, soluble in potash and in alkaline carbonates.

Zinc plate produces a black precipitate of metallic tellurium.

Copperas produces a black powder, which on being rubbed, assumes a metallic lustre.

TREATMENT OF ORES.

Assay—Dry Way.

(FROM RANDALL'S QUARTZ OPERATORS' HAND BOOK.)

Galena or Ores of Lead Containing Sulpher.

Case 1.

Put in a crucible, usually earthen.

Powdered ore (by weight)	10 parts.
Iron in thin strips or plates	1 to 3 parts.
Black flux	30 parts.

And a thick layer of common salt.

Cover the crucible with an earthen cover, fuse the contents. Employ first a low heat, increase it gradually to bright red and continue it at this degree about half an hour. Settle the metallic particles by gently rapping the crucible. Cool and extract the button of lead.

Assay of Oxidized Ores of Lead.

Case 2.

Powdered ore (by weight)	10 parts.
Carbonate of soda	30 to 40 parts.
Pulverized charcoal	3 parts.
Iron in strips or plates, if sulphur is present	1 part.

Cover with salt and proceed as in case 1.

Assay of Iron Ore.

Case 3.

Powdered and roasted ore	2 parts.
Flour spar	1 part.
Charcoal	1 part.
Cover with common salt	4 parts.

Fuse, cool and weigh the button of cast-iron.

Assay of Copper Ores Containing Iron.

Case 4.

Powdered ore	1 part.
Black flux	3 parts.

Fuse, cool and extract copper button.

Copper Ores Containing Sulphur and Iron.

Case 5.

First—Powdered and roasted ore	1 part.
Dried borax	1 part.

Fuse, cool, extract from the slag the crude copper button, which pulverize and wash the powder, stirring it in the mean time, till it ceases to evolve sulphurous acid. Then increase and continue the temperature to and at white heat.

Second—Mix in the same crucible, roasted matter	1 part.
Black flux	3 to 4 parts.

Cover with fused borax, fuse, cool and extract the button of copper.

Assay of Copper Ores Containing Arsenic.

Case 6.

Fuse, pulverize the matter, and roast the powder as in case 5 till garlic ceases to evolve. Reduce the matter with black flux; cupel the button in a bone-ash cupel with pure lead. Cool and weigh the button of copper.

Assay of Gold or Silver or Gold and Silver Ores.

Case 7.

Powdered ore	4 parts.
Litharge	4 parts.
Black flux	3 parts.

The ores containing lead, omit the litharge. If rich in pyrites, employ litharge and nitre. If the button contains gold, silver and copper, add to it silver and lead, so that the alloy shall consist, as near as practicable, of

Gold	1 part.
Silver	3 parts.
Lead	12 to 16 parts.

First fuse the lead in a bone-ash cupel, then add the gold and silver; continue the heat till brightening occurs. Cool and weigh button.

PARTING OF GOLD. Anneal, beat the button into a thin sheet, roll it into a "cornet." Dissolve the silver in it first in diluted nitric acid, then in concentrated nitric acid, wash, dry and heat the cornet of gold.

Assay of Horn Silver or Chloride of Silver.

Case 8.

Horn silver pulverized	1 part.
Carbonate of soda	3 parts.

Mix, fuse, cool and extract button of silver.

Black Flux.

Black flux is prepared by introducing gradually in small quantities into a crucible heated to a very dull redness, a mixture of either two parts of cream of tartar and one of nitre, or equal parts of cream of tartar and nitre.

White Flux.

White flux is prepared in a manner similar to that of black flux, except that the mixture consists of one part of cream of tartar and two parts of nitre.

Silver Mill and Treatment of Silver Ores (Raw).

The machinery of a silver mill consists essentially of the motor and connections; the rock breaker, self-feeder, bat-

teries, tanks, grinders and amalgamators, separators, agitators, concentrators, amalgam safe or press, retorts, crucible and ingot molds. The various machines in the order of their enumeration, from rock breaker to concentrator inclusive, are arranged on descending steps, so that the ore under treatment passes through them for the most part by its own gravity, and thereby requiring the least possible manual labor.

Rock-Breaker.

The ore coming from the mines, in fragments varying in size from an inch to a foot and upward in diameter is reduced in the rock breaker to an inch or so in diameter. Our Wheeler rock breaker with feed opening 9 inches by 15 inches, making one hondred and seventy-five revolutions per minute, will reduce from one hundred to one hundred and fifty tons of quartz rock, depending on its hardness and toughness, from and to the sizes above specified, requiring from four to six horse-power.

Self-Feeder.

Thence the crushed ore falls into the self-feeder, which discharges it into the batteries with greater uniformity of delivery than is possible to be attained by hand feeding. One self-feeder is capable of supplying five stamps, or from twelve to fifteen tons per twenty-four hours, at an expense of say one-half horse-power.

Batteries.

Thence after reduction by the stamps in the battery, the granulated ore passes through Russia iron screens, usually of number four or number five fineness, into large settling tanks.

Each stamp weighing seven hundred and fifty pounds, and making ninety drops, eight inch each, per minute, will crush about three tons of hard tough rock in twenty-four hours, and requires nearly three-fourths of one horse-power per ton of ore reduced.

Tanks.

The crushed ore is well settled in the tanks. These are arranged in series, so that that portion of the ore which per-

chance may be borne along by the water through the upper of the series, shall be caught in the next lower, and so on to the satisfaction of a rigid test. Tanks vary greatly in size. One of common size is five by seven feet, three feet deep, and holds about four tons.

Grinders and Amalgamators.

The granulated ore is fed by charges from the tanks into the grinders and amalgamators. In these it is reduced by grinding to an impalpable paste, *slum* or slime, condition in contact with quicksilver with which its metallic portions amalgamate.

A charge of ore is from one-half ton to a ton in weight, according to the size of the machine.

A grinder and amalgamator of the best design, its muller making sixty-five revolutions per minute, will reduce eight charges of ore, fifteen hundred pounds each, from the granular state as it comes from the batteries to the slime condition, in twenty-four hours, at an expense of four and one-half horse-power. Two grinders are required for five stamps.

Separator.

Thence the stopper removed from the bottom of the grinder and amalgamator, the ore-pulp runs into the separator, where, prevented from packing by means of revolving stirrers, it if thoroughly washed. The heavier or amalgam portion settling to the bottom, is swept by the stirrers into grooves prepared for its reception. The pulp (gangue portion) is then drawn off through a series of openings, of different heights, in the side of the separator into the agitators, or suffered to run off as waste tailings or otherwise. The drawing off is effected first at the highest opening, then at the next lower and so on to the lowest. The separator is then cleaned up by hand, and the amalgam freed of its excess of quicksilver in the amalgam safe or press. One separator is employed for two grinders and amalgamators and requires about two horse-power.

Agitator.

The agitator is employed for the double purpose of gathering any amalgam which may escape the separator, and for preventing the pulp drawn into it by charges from the separator from packing, or for keeping it buoyed up. An agitator of ordinary size requires about one horse-power. The pulp flows continuously from the agitator into the concentrator.

Concentrator.

In the concentrator, the pulp diluted with clean water is subjected to a short, rapid vibratory motion, by which means its lighter portions are buoyed up, while its heavier (for the most part the richer) settle and concentrate at the lowest part of the machine, prepared for their reception, whence they are returned to the grinders and amalgamators for further treatment which is similar to the first in the same machines. A concentrator requires about two horse-power. Circular buddles and revolving blankets are also very efficient concentrating machines.

Amalgam Safe.

The amalgam, cleaned-up from the separator, is put in an amalgam safe and freed of its excess of quicksilver. Sometimes a press is used for this purpose.

Retort.

Thence the dry amalgam is placed in a retort and heated at a cherry red heat until the fumes of mercury cease.

Crucible and Ingot Mold.

Thence the retorted amalgam is melted in a crucible and poured into the ingot mold.

From which it is taken as bullion to the commercial mart or to the mint.

The Golden State and Miners' Iron Works Gold Mills and the Treatment of Gold-Bearing Rock.

Gold mills are in far greater variety than silver mills for the reduction of the vein stone, concentration of the richer portions of the material under treatment and the amalgamation of the precious metals.

1st. If the gold is very fine, rich and uniformly diffused through the rock, it can be worked to advantage by nearly the same process as that described for working silver ores.

2d. If the gold in the rock is contained mostly in the sulphurets, concentrators and amalgamators should be employed immediately after the batteries, the concentrated portions ground, worked in separators and treated in another series of concentrators, whence the portions saved should be reground and worked again in the separator.

3d. If the gold is coarse and clean in the rock, grinders and separators will not be required.

4th. If the gold is coarse and coated, it is advisable to crush, grind, separate and concentrate as the ore passes continuously through the different machines.

Modifications in machinery must be made according to the character of the rock and the gold it contains.

The weight of authority is, with respect to wet crushing, in favor of amalgamating in the battery. The quicksilver should be fed in small quantities into the batteries and fed often. The rule is to so feed the quicksilver that the amalgam passing the screens can be indented by a gentle pressure of the finger and yet be so firm as to retain the indentation. Copper plate silvered is frequently employed both inside and outside of the battery, but it cannot be relied on as an efficient amalgamator; it, however, may be employed as an auxiliary with seeming advantage. A careful use of sodium amalgam in preparing copper plate, also in cases of "flouring" and "sickening" of the quicksilver, and in cleaning up, especially when a portion of the mercury and amalgam is in a finely divided state or "scum form," is often made with highly beneficial results. The ratio observed is, one part of sodium to two thousand, or twenty-five hundred, parts of quicksilver by weight.

GOLDEN STATE AND MINERS' IRON WORKS.

Power and Water Required for a 40 Stamp Silver Mill Working 100 Tons of Ore Per Day.

	H. P.
1 Rock breaker, shafting 175 revolutions per minute..	5.0
8 Self-feeders,.......	2.0

40 Stamps, each 750 lbs, making 90 8-in. drops a min..	54 5
16 Grinders and amalgamators, each 65 revs. per min..	72.0
8 Separators, each making 8 revolutions per min.....	16.0
1 Agitator, making 50 revolutions per min...........	3.0
4 Concentrators, each making 200 revs. per min.......	8.0
Friction, 33 1-3 per cent..........................	53.5
Total horse-power..................................	214.0

Water Required for a 40 Stamp Silver Mill Working 100 Tons of Ore a Day.

214 Horse-Power........	2.56 cu. ft. per min	=	2.13 M in.
40 Stamps..............	10.00 cu. ft. per min	=	8.33 M in.
16 Grinders and amals..	6.00 cu. ft. per min	=	5.00 M in.
8 Separators...........	1.80 cu. ft. per min	=	1.50 M in.
Total water required.....	20.36 cu. ft. per min	=	16.96 M in.

For the reduction of gold and silver ores by stamps, the usual ratio of the weight of water to that of rock is as nine to two (9 : 2)—

Stamping requires...........	144. cu ft water to 1 ton ore.
Grinding and amal.........	86.4 cu ft. water to 1 ton ore.
Separating or settling.......	25 9 cu ft. water to 1 ton ore.
Silver mill including H. P..	293.2 cu ft. water to 1 ton ore.

TABLE 24.

WATER REQUIRED IN WORKING QUARTZ, EACH STAMP WORKING TWO AND A HALF TONS OF ORE A DAY.

	Cu. ft.		Pounds.		M in.
1 Stamp requires....................	.25	=	15.625	=	.208
1 Grinder and amalgamator.........	.375	=	23.4375	=	.3125
1 Separator........................	.225	=	14.0625	=	.1875
Silver mill (including H.P.) per stamp	.509	=	31.8125	=	.424

REMARK. In working the Lake Superior copper ores, twenty cubic feet of water to one cubic foot of ore employed. This is equivalent to eight to one by weight.

Question. How many miners' inches are required for an eighty stamp silver mill, including power?

Answer, In Table 24, opposite silver mill, in column of miners' inches, find .424. This multiplied by the given number of stamps gives, .424 × 80 = 33.92 miners' inchesrequired.

TABLE 25.

NUMBER, THICKNESS AND WEIGHT OF ONE SQUARE FOOT OF SHEET IRON.

Haswell.

Birmingham Guage.						American Guage.					
No.	Th'k in.	Lbs.	No.	Th'k in.	Lbs.	No.	Th'k in.	Lbs.	No.	Th'k in.	Lbs.
0000	.454	18.35	17	.058	2.34	0000	.46	18.63	19	.036	1.45
000	.425	17.18	18	.049	1.98	000	.41	16.58	20	.032	1.29
00	.38	15.36	19	.042	1.70	00	.365	14.77	21	.028	1.15
0	.34	13.74	20	.035	1.42	0	.325	13.15	22	.025	1.03
1	.3	12.13	21	.032	1.29	1	.289	11.7	23	.023	.913
2	.284	11.48	22	028	1.32	2	.258	10.43	24	.020	.814
3	.259	10.47	23	.025	1.01	3	.229	9.29	25	.018	.724
4	.238	9.62	24	.022	.889	4	.204	8.27	26	.016	.644
5	.22	8.89	25	.02	.808	5	.182	7.37	27	.014	.574
6	.203	8.21	26	.018	.723	6	.162	6.56	28	.013	.511
7	.18	7.28	27	.016	.647	7	.144	5.84	29	.011	.455
8	.165	6.67	28	.014	.566	8	.128	5.20	30	.010	.405
9	.148	5.98	29	.013	.525	9	.114	4.63	31	.009	.360
10	.134	5.42	30	.012	.485	10	.102	4.13	32	.008	.321
11	.12	4.85	31	.010	.404	11	.091	3.67	33	.007	.286
12	.109	4.41	32	.009	.364	12	.081	3.27	34	.0063	.254
13	.095	3.84	33	.008	.323	13	.072	2.92	35	.0056	.226
14	.083	3.36	34	.007	.283	14	.064	2.59	36	.005	.202
15	.072	2.91	35	.005	.202	15	.057	2.31	37	.0045	.180
16	.065	2.63	36	.004	.162	16	.051	2.05	38	.004	.159
						17	.045	1 83	39	.0035	.142
						18	.040	1.63	40	.0031	.127

TABLE 26.

WEIGHT AND STRENGTH OF IRON BOLTS.

Trautwine.

Ends Enlarged.			Ends not Enlarged.		Ends Enlarged.			Ends not Enlarged.	
Diameter of Shank.	Weight Per Foot Run.	Breaking Strain.	Diameter of Shank.	Weight Per Foot Run.	Diameter of Shanks.	Weight Per Foot Run.	Breaking Strain.	Diameter of Shank.	Weight Per Foot Run.
Ins.	Pds.	Pds.	Ins.	Pds.	Ins.	Pds.	Pds.	Ins.	Pds.
1/8	.0414	549			1 3/4	8.10	102368	2.14	12.0
1/4	.165	2202	.35	.321	1 7/8	9.30	117000	2.30	13.8
3/8	.372	4950	.50	.654	2	10.6	133728	2.45	15.7
1/2	.661	8803	.66	1.14	2 1/4	13.4	160384	2.73	19.5
5/8	1.03	13754	.80	1.67	2 1/2	16.5	198016	3.02	23.9
3/4	1.49	19779	.96	2.41	2 3/4	20.0	239456	3.30	28.5
7/8	2.03	26880	1.12	3.26	3	23.8	284938	3.60	33.9
1	2.65	35168	1.27	4.27	3 1/2	32.4	366264	4.12	44.4
1 1/8	3.25	42336	1.42	5.28	4	42.3	478464	4.70	57.8
1 1/4	4.13	52192	1.55	6.39	4 1/2	53.6	570080	5.25	72.9
1 3/8	5.00	63168	1.72	7.74	5	66.1	703808	5.80	88.7
1 1/2	5.95	75264	1.87	9.20	5 1/2	80.0	798336	6.36	106.0
1 5/8	6.99	88256	2.00	10.6	6	95.2	949984	6.90	126.0

REMARKS. The breaking strain of a square bar is one and one-fourth (1.25) times that of a round bar, whose diameter is equal to the side of the square.

The breaking strain of copper bolts is found by multiplying the breaking strain of iron bolts of the same size, by eight-tenths (.8).

TABLE 27.

ROUND ROPES.

Iron Wire Rope.		Steel Wire Rope.		Hemp Rope.		Chain.		Breaking Strain.	Working Load.
Circum.	Weight of 100 Feet.	Circum.	Weight of 100 Feet.	Circum.	Weight of 100 Feet.	Size Bar in Link.	Weight of 100 Feet.		
Ins.	Pds.	Ins.	Pds.	Ins.	Pds.	Ins.	Pds.	Tons.	Pds.
1¾	40.	1½	25.	3	63.	7-16	183.	5.	1,666
2	52	1⅝	33.	5	100.	1·2	266.	7.	2,333
2¼	66.	1⅞	50.	5½	117.	9-16	300.	8.5	2,666
2½	83.	2	59.	6	130.	19-32	341.	11.	3,700
2¾	110.	2⅛	67.	6½	145.	5-8	400.	13.	4,300
3	139	2⅜	83.	7¼	185.	11-16	466.	15.	5,000
3⅜	170.	2½	91.	8	236.	3-4	533.	19.	6,300
3¾	240.	3⅛	130	9	297.	13-16	650.	24.	8,000
4	260.	3⅜	153.	9½	330.	7-8	750.	28.	9,400
4½	285	3½	166.	10½	428.	1.	933.	36.	12,000

TABLE 28.

FLAT ROPES.

Iron Wire Rope.		Steel Wire Rope.		Hemp Rope.		Breaking Strain.	Working Load.
Size. Inches.	Wgt. per Ft. Pounds.	Size. Inches.	Wgt. per Ft. Pounds.	Size. Inches.	Wgt. per Ft. Pounds.	Tons.	Pounds.
$2\frac{1}{2} \times \frac{1}{2}$	2.20	$2\frac{1}{8} \times \frac{3}{8}$	1.40	$5 \times 1\frac{1}{4}$	4 08	23.	5,800
$3 \times \frac{5}{8}$	2.75	$2 \times \frac{1}{2}$	1.67	$5\frac{3}{4} \times 1\frac{1}{2}$	4.75	28.	7,150
$4 \times$ 11–16	4.25	$2\frac{3}{4} \times \frac{5}{8}$	2.50	$8\frac{1}{2} \times 2\frac{1}{4}$	7.67	45.	12,300
$5\frac{3}{8} \times \frac{3}{4}$	5.75	$3\frac{1}{2} \times \frac{5}{8}$	3.33	$10 \times 2\frac{1}{2}$	10.25	60.	15,300

TABLE 29.

WEIGHT OF A LINEAR FOOT OF ROUND AND SQUARE BAR IRON.

Dia. or Side.	Round Bars.	Square Bars.	Dia. or Side.	Round Bars.	Square Bars.	Dia. or Side.	Round Bars.	Square Bars.
Ins.	Pds.	Pds.	Ins.	Pds.	Pds.	Ins.	Pds.	Pds.
¼	.16	.21	3¼	28 05	35.70	6½	112 1	142.8
⅜	.37	.47	3⅜	30.24	38.50	6¾	120.9	154.4
½	.66	.84	3½	32.52	41.40	7	130.0	165.6
⅝	1.04	1.32	3⅝	34.88	44.41	7¼	139.5	177.6
¾	1.49	1.90	3¾	37.33	47.53	7½	149.3	190.1
⅞	2.03	2.58	3⅞	39.86	50.75	7¾	159.4	203.0
1	2.65	3.38	4	42 4	54.00	8	169.8	216.3
1⅛	3.36	4.27	4⅛	45.1	57.5	8¼	180.6	230.0
1¼	4.17	5.28	4¼	47 9	61.0	8½	191.8	244.2
1⅜	5.01	6.39	4⅜	50.8	64.7	8¾	203.2	258.8
1½	5.97	7.60	4½	53.7	68.4	9	215.0	273.7
1⅝	7.01	8.92	4⅝	56.7	72.3	9¼	227.1	289.2
1¾	8.12	10.35	4¾	59.9	76.2	9½	239.6	305.0
1⅞	9.33	11.88	4⅞	63.0	80.3	9¾	252.3	321.3
2	10.61	13.52	5	66.7	84.4	10	266.2	337.9
2⅛	11.98	15.26	5⅛	69.7	88.7	10¼	278.9	355.1
2¼	13.44	17.11	5¼	73.1	93.1	10½	292.6	372.6
2⅜	14.97	19.06	5⅜	76.7	97.6	10¾	306.8	390.6
2½	16.68	21.12	5½	80.3	102.2	11	321.2	408.9
2⅝	18.29	23.29	5⅝	84.0	106.9	11¼	336.0	427.8
2¾	20.07	25.56	5¾	87.7	111.7	11½	351.1	447.0
2⅞	21.94	27.93	5⅞	91.6	116.6	11¾	366.5	466.6
3	23.88	30.41	6	95.5	121.6	12	382.2	486.6
3⅛	25.92	33.01	6¼	103.7	132.0	....	.....	....

TABLE 30.

WEIGHT OF A LINEAR FOOT OF FLAT BAR IRON IN POUNDS.

BREADTH	THICKNESS IN PARTS OF AN INCH.								
Inches.	¼	5-16	⅜	7-16	½	⅝	¾	⅞	1.
1	.83	1.04	1.25	1.46	1.67	2.08	2.50	2.92	3.34
1⅛	.93	1.17	1.40	1.64	1.87	2.34	2.81	3.28	3 75
1¼	1.04	1.30	1.56	1 82	2.08	2.60	3.13	3.65	4.17
1⅜	1 14	1.43	1.72	2 00	2.29	2.87	3 44	4.01	4.59
1½	1.25	1 56	1.87	2.19	2.50	3.13	3.75	4.38	5.00
1⅝	1.35	1.69	2.03	2.37	2.71	3.39	4.07	4.70	5.43
1¾	1.46	1.82	2.19	2.55	2.92	3.65	4.38	5.11	5.84
1⅞	1.56	1.95	2.34	2.74	3.13	3.91	4.69	5.47	6.26
2	1.67	2.08	2.50	2 92	3.34	4.17	5 01	5 86	6.68
2⅛	1.77	2.21	2.66	3.10	3.55	4.43	5.32	6.21	7.10
2¼	1.87	2.34	2.81	3.28	3.76	4.69	5.63	6.57	7.52
2⅜	1.98	2.47	2.97	3.47	3.96	4.95	5.95	6.94	7.93
2½	2.08	2.60	3.13	3.65	4.17	5.21	6.26	7.30	8.35
2⅝	2.19	2.74	3.28	3.83	4.38	5.47	6.57	7.67	8.77
2¾	2.29	2.87	3.44	4.01	4.59	5.74	6.88	8.03	9.18
2⅞	2.40	3.00	3.60	4.20	4.80	6.00	7.20	8.40	9.60
3	2.50	3.13	3.75	4.38	5.01	6.26	7.51	8.76	10 02
3¼	2 71	3.39	4.07	4.74	5.43	6 78	8.14	9.49	10.86
3½	2 92	3.65	4.38	5.11	5.84	7 30	8.76	10.23	11.69
3¾	3.13	3.91	4.68	5.47	6.26	7.82	9.39	10.95	12.52
4	3.34	4.17	5.00	5.84	6.68	8.35	10.02	11.69	13.36
4¼	3.54	4.43	5.32	6.21	7.09	8.87	10.64	12.42	14.19
4½	3.75	4.69	5.63	6.57	7.51	9.39	11.27	13.52	15.03
4¾	3.96	4.95	5 94	6.94	7.93	9.91	11.89	13.88	15.86
5	4 17	5.21	6.27	7.30	8.35	10.44	12.52	14.61	16.70
5¼	4.38	5.47	6.57	7.67	8.76	10.96	13.14	15.34	17.53
5½	4.59	5.73	6.88	8.03	9.18	11.48	13.77	16.07	18.37
5¾	4.80	6.00	7.20	8.40	9.60	12.00	14.40	16.80	19.20
6	5.01	6.25	7.51	8.76	10.02	12.53	15.03	17.53	20.05

TABLE 31.

WEIGHT OF PLATE IRON PER SQUARE FOOT.

THICKNESS IN PARTS OF AN INCH.

⅛	3-16	¼	5-16	⅜	7-16	½	9-16	⅝	11-16	¾	13-16	⅞	15-16	1
5.	7.5	10.	12.5	15.	17.5	20.	22.5	25.	27.5	30.	32.5	35.	37.5	40.

TABLE 32.

WEIGHT OF CAST IRON PIPE ONE FOOT LONG.

THICKNESS OF METAL.

BORE.	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
Inches	Pds.	Pds.	Pds.	Pds.	Pds.	Pds.	Pds.	Pds.	Pds.
1	3.1	5.1	7.4	10.0	12.9	16.1	19.6	23.5	27 6
1¼	3.7	6.0	8.6	11.5	14.7	18.3	22.1	26.2	30.7
1½	4.3	6.9	9.8	13.0	16.6	20.4	24.5	29.0	33.7
1¾	4.9	7.8	11.1	14.6	18.4	22.6	27.0	31.8	36.8
2	5.5	8.8	12.3	16.1	20.3	24.7	29.5	34.5	39.9
2¼	6.1	9.7	13.5	17.6	22.1	26 8	31.9	37.3	43.0
2½	6.7	10.6	14.7	19.2	23.9	28.9	34.4	40.0	46.0
2¾	7.4	11.5	16.0	20.7	25.7	31.1	36.8	42.8	49.1
3	8.0	12.4	17.2	22.2	27.6	33.3	39.3	45.6	52.2
3¼	8.6	13.3	18.4	23.8	29.5	35.4	41.7	48.3	55.2
3½	9.2	14.2	19.6	25.3	31.3	37 6	44.2	51.1	58.3
3¾	9.8	15.2	20.9	26.6	33.1	39.9	46.6	53.8	61.4
4	10.4	16.1	22.1	28.4	35.0	41.9	49.1	56.6	64.4
4¼	11.1	17.1	23.4	30.0	36.9	44.1	51.6	59.4	67.6
4½	11.7	18 0	24.5	31.4	38.7	46.2	54.0	62.1	70.6
4¾	12.3	18.9	25.8	33.0	40.5	48.3	56.5	64.9	73.6
5	12.9	19.8	27.0	34.5	42.2	50.5	58.9	67.6	76.7
5¼	13.5	20.7	28.2	36.1	44.2	52.6	61.4	70.4	79.8
5½	14.1	21.6	29.5	37.6	46.0	54.8	63.8	73.2	82.8
5¾	14.7	22.6	30.7	39.1	47.9	56.9	66.3	76.0	85.9
6	15.3	23.5	31.9	40.7	49.7	59.1	68.7	78.7	88.8
6¼	16.0	24 4	33.1	42.2	51.5	61.2	71.2	81.2	92.0
6½	16.6	25.3	34.4	43.7	53.4	63.4	73.4	84.2	95.1
6¾	17.2	26.2	35.6	45.3	55.2	65.3	76.1	87 0	89.2
7	17.8	27.2	36.8	46.8	56.8	67.7	78.5	89.7	101.2
7¼	18.4	28.1	38.1	48.1	58.9	69.8	81.0	92.5	104.2
7½	19.0	29.0	39.1	49.9	60.7	72.9	83.5	95.3	107.4
7¾	19.6	29.7	40.5	51.4	62.6	74.1	85.9	98.0	110.5
8	20 2	30.8	41.7	52.9	64.4	76.2	88.4	100.8	113.0
8¼	20.9	31.7	43.0	54.5	66.3	78.4	90.8	103.5	116.6
8½	21.6	32.9	44.4	56.2	68.3	80.8	93.5	106.5	119.9
8¾	22.1	33.6	45.5	57.5	70.0	82.7	95.7	109.1	122.7
9	22.7	34.5	46.6	59.1	71.8	84.8	98.2	111.8	125.8

TABLE 33.

RELATIVE POWERS OF DIFFERENT SECTIONS OF EQUAL AREAS TO RESIST TORSION—SOLID CYLINDERS BEING UNITY.

Solid Cylinder.	Solid Square.	Hollow Cylinder whose Inner Diameter is to the Outer				
		As 4 to 10.	As 5 to 10.	As 6 to 10.	As 7 to 10.	As 8 to 10.
1	.87	1.26	1.44	1.7	2·08	2.74

TABLE 34.

WEIGHT AND BULK OF SUBSTANCES.

Names of Substances.	Cubic foot. Pds.	Cubic foot. pr ton	Names of Substances.	Cubic foot. Pds.	Cubic foot. pr ton
Cast Iron............	450.5	4.97	Sand	94.5	23.7
Wrought Iron.......	486.6	4.60	Granite..............	139.0	16.1
Steel	489.8	4.57	Earth, loose	78.6	28.5
Copper	555.0	4.03	Water, *salt* (Sea)	64.3	34.8
Lead	707.7	3.16	Water, *fresh*	62.5	35.9
Brass................	537.7	4.16	Ice	58.08	38.56
Tin	456.0	4.91	Gold..................	1013.0	2.21
Pine, White.........	29.56	75.60	Silver	551.0	4.07
Pine, Yellow.........	33.81	66.2	Coal, Anthracite.....	53.0	42.3
Mohogany	66.40	33.8	Coal, Bituminous....	50.0	44.8
Marble, Common....	141.0	15.9	Coal, Cumberland....	53.0	42.3
Mill Stone...........	130.0	17.2	Coal, Charcoal	18.2	123.0
Oak, Live............	70.0	32.0	Coke, Midlothian....	32.7	68.5
Oak, White..........	45.2	49.5	Coke, Cumberland...	31.57	70.9
Clay....	101.3	22.1	Coke, natur'l Virginia	46.64	48.3
Concrete, ordinary...	115.0	19.5	Conventional rate of Stone Coal, 28 bushels, (5 pecks per bushel), 1 ton......	....	48.56
Brick................	100.0	22.4			
Plaster Paris........	105.0	21.3			

TABLE 35.

WEIGHT OF CAST IRON BOLTS.

Trautwine.

Diam. Inches.	Pds.	Diam. Inches.	Pds.	Diam. Inches.	Pds.	Diam. Inches.	Pds.
½	.017	3	3.68	5½	22.7	10	136.0
¾	.058	3¼	4.68	5¾	25.9	10½	158.
1	.136	3½	5.85	6	29.4	11	182.
1¼	.266	3¾	7.19	6½	37.4	11½	207.
1½	.460	4	8.73	7	46.8	12	236.
1¾	.731	4¼	10.5	7½	57.5		
2	1.07	4½	12.4	8	69.8		
2¼	1.55	4¾	14.6	8½	83.7		
2½	2.13	5	17.0	9	99.4		
2¾	2.83	5¼	19.8	9½	117.0		

TABLE 36.

RELATIVE WEIGHTS OF METALS, CAST IRON BEING UNITY.

P. M. Randall.

Names.	Co-efficient	Names.	Co-efficient
Cast Iron..........	1.000	Steel...............	1.086
Wrought Iron.....	1.072	Lead...............	1.574
Copper, rolled.....	1.226	Platinum..........	2.953
Tin...............	1.015	Gold...............	2.702
Zinc...............	.947	Silver...............	1.448
Brass...............	1.170	Nickel...............	1.142
Antimony.........	.933	Mercury	1.880

TABLE 37.

NAILS AND SPIKES.

Name.	Length In.	No. in a Pound.	Name.	Length In.	No. in a Pound.
3-Penny......	1	557	12-Penny......	3	54
4-Penny......	1¼	353	20-Penny......	3½	34
5-Penny.	1¾	232	Spikes	4	16
6-Penny......	2	175	Spikes	4½	12
7-Penny......	2¼	141	Spikes	5	10
8-Penny......	2½	101	Spikes	6	7
10-Penny......	2¾	68	Spikes........	7	5

TABLE 38.

EXPANSION OF SOLIDS BY HEAT, AND THEIR MELTING POINTS FAHR.

Trautwine.

Names.	For 1° Fahr.		For 180° Fahr.		Melting Point in Deg.
	1 part in	⅛ in. in	1 part in	⅛ in. in	
Fire Brick.............	365220	3804	2029	21.14	
Granite..................	207810	2165	1155	12.03	
Glass, rod............	221400	2306	1230	12.81	
Marble, gran. white, dry.	173000	1802	961	10.00	
Marble, black, compact.	405000	4219	2250	23.44	
Cast Iron................	162000	1688	900	9.38	2786
Iron, rolled	149940	1562	833	8.68	
Steel.............	151200	1575	840	8.75	
Copper, average	104400	1088	580	6.04	2174
Brass, average	97740	1018	543	5.66	1873
Lead, average..........	63180	658	351	3.66	622
Zinc....................	61920	645	344	3.58	772

TABLE 39.

RELATIVE POWER OF METALS TO RESIST TORSION—WROUGHT IRON BEING UNITY.

Wrought Iron.........	1.00	Copper...............	.22
Cast Iron.............	.90	Tin....................	.13
Cast Steel.............	1.93	Lead	.10
Gun Metal............	.27	Brass..................	.25

TABLE 40.

FRICTION—PRESSURE BETWEEN A PAIR GREASED SURFACES, WHICH IN PRACTICE WILL NOT FORCE OUT THE UNGUENT.

Kind of Bearings.	Pressure per Square Inch.
For Cylindrical Journals....	450 to 150 pounds.
For Flat Pivots..................................	2,240 pounds.
For Timber Ways used in launching ships,	50 pounds.

TABLE 41.

VELOCITY OF FALLING BODIES IN VACUUM.

Time in Seconds............	1	2	3	4	5	6	7	8	9	10
Space in Feet...............	16	64	145	257	402	579	788	1030	1303	1609
Velocity acquired at end of the time..................	32	64	96	128	161	193	257	275	[illegible]	[illegible]

TABLE 42.

CIRCUMFERENCE AND AREAS OF CIRCLES.

Dia.	Cir.	Area.	Dia.	Cir.	Area.	Dia.	Cir.	Area.
1-32	.0981	.00076	2	6.283	3.141	7	21.99	38.484
1-16	.1963	.00306	⅛	6.675	3.546	¼	22.77	41.282
⅛	.3926	.01227	¼	7.068	3.976	½	23.56	44.178
3-16	.5890	.02761	⅜	7.461	4.430	¾	24.34	47.173
¼	.7854	.04908	½	7.854	4.908	8	25.13	50.265
5-16	9817	.07669	⅝	8.246	5.411	¼	25.91	53.456
⅜	1.178	.1104	¾	8.639	5.939	½	26.70	56.745
7-16	1 374	.1503	⅞	9.032	6.491	¾	27.48	60.132
½	1.570	.1963	3	9.424	7.068	9	28.27	63.617
9-16	1.767	.2485	¼	10.21	8.295	¼	29.05	67.200
⅝	1.963	.3067	½	10.99	9.621	½	29.84	70.882
11-16	2.159	.3712	¾	11.78	11.044	¾	30.63	74.662
¾	2.356	.4417	4	12.56	12.566	10	31.41	78.540
13-16	2.552	.5184	¼	13.35	14.186	¼	32.20	82.516
⅞	2.748	.6013	½	14.13	15.904	½	32.98	86.590
15-16	2.945	.6902	¾	14.92	17.720	¾	33.77	90.762
1	3.141	.7854	5	15.71	19.635	11	34.55	95.033
⅛	3.534	.9940	¼	16.49	21.647	¼	35.34	99.402
¼	3.927	1.227	½	17.27	23.758	½	36.12	103.86
⅜	4.319	1.484	¾	18.06	25.967	¾	36.91	108.43
½	4.712	1.767	6	18.84	28.274	12	37.69	113.09
⅝	5.105	2.073	¼	19.63	30.679	¼	38.48	117.85
¾	5.497	2.405	½	20.42	33.183	½	39.27	122.71
⅞	5.890	2.761	¾	21.20	35.784	¾	40.05	127.67

TABLE 42. (Continued,)

CIRCUMFERENOE AND AREAS OF CIRCLES.

Dia.	Cir.	Area.	Dia.	Cir.	Area.	Dia.	Cir.	Area.
13	40.84	132.73	19	59.69	283.52	30	94.24	706.86
¼	41.62	137.88	¼	60.47	291.03	½	95.81	730.61
½	42.41	143.13	½	61.26	298.64	31	97.38	754.76
¾	43.19	148.48	¾	62.04	306.35	½	98.96	779.31
14	43.98	153.93	20	62.83	314.16	32	100.5	804.24
¼	44.76	159.48	½	64.40	330.06	½	102.1	829.57
½	45.55	165.13	21	65.97	346.36	33	103.6	855.30
¾	46.33	170.87	½	67.54	363.05	½	105.2	881.41
15	47.12	176.78	22	69.11	380.13	34	106.8	907.92
¼	47.90	182.65	½	70.68	397.60	½	108.3	934.82
½	48.69	188.69	23	72.25	415.47	35	109.9	962.11
¾	49.48	194.82	½	73.82	433.73	½	111.5	989.80
16	50.26	201 06	24	75.39	452 39	36	113.0	1017.8
¼	51.05	207.39	½	76.96	471.43	½	114.6	1046.3
½	51.83	213.82	25	78.54	490·87	37	116.2	1075.2
¾	52.62	220.35	½	80.10	510.70	½	117.8	1104.4
17	53.40	226.98	26	81.68	530.93	38	119.3	1134.1
¼	54.19	233.70	½	83.25	551.54	½	120.9	1164.1
½	54.97	240.52	27	84.82	572.55	39	122.5	1194.5
¾	55.76	247.45	½	86.39	593.55	½	124.0	1225·4
18	56.54	254.46	28	87.96	615 75	40	125.6	1256.6
¼	57.33	261.58	½	89.53	637.94	½	127.2	1288.2
½	58.11	268.80	29	91.10	660.52	41	128.8	1320.2
¾	58.90	276.11	½	92.67	683.49	½	130.3	1352.5

TABLE 42. (Continued.)

CIRCUMFERENCE AND AREAS OF CIRCLES.

Dia.	Cir.	Area.	Dia.	Cir.	Area.	Dia.	Cir.	Area.
42	131.9	1385.4	54	169.6	2290.2	66	207.3	3421.2
½	133.5	1418.6	½	171.2	2332.8	½	208.9	3473.2
43	135.0	1452.2	55	172.7	2375.8	67	210.4	3525.6
½	136.6	1486.1	½	174.3	2419.2	½	212.0	3578 4
44	138.2	1520.5	56	175.9	2463.0	68	217.6	3631.6
½	139.8	1555.2	½	177.5	2507.1	½	215.1	3685.2
45	141.3	1590.4	57	179.0	2551.7	69	216.7	3739 2
½	142.9	1625.9	½	180.6	2596 7	½	218.3	3793.6
46	144.5	1661.9	58	182 2	2642.0	70	219.9	3848.4
½	146.0	1698.2	½	183.7	2687.8	½	221.4	3903.6
47	147.6	1734.9	59	185.3	2733.9	71	223.0	3959.2
½	149.2	1772.0	½	186.9	2780.5	½	224.6	4015.1
48	150.7	1809.5	60	188.4	2827.4	72	226.1	4071.5
½	152.3	1847.4	½	190.0	2874.7	½	227.7	4128.2
49	153.9	1885.7	61	191.6	2922.4	73	229.3	4185 3
½	155.5	1924.4	½	193.2	2970.5	½	230.9	4242.5
50	157.0	1963.5	62	194.7	3019.0	74	232.4	4300.8
½	158.6	2002.9	½	196.3	3067.9	½	234.0	4359.1
51	160.2	2042.8	63	197.9	3117.2	75	235.6	4417.8
½	161.7	2083.0	½	199.4	3166.9	½	237.1	4476 9
52	163.3	2123.7	64	201.0	3216.9	76	238.7	4536.4
½	164.9	2164.7	½	202.6	3267.4	½	240.3	4596.3
53	166.5	2206.1	65	204.2	3318.3	77	241.9	4656.6
½	168.0	2248.0	½	205.7	3369.5	½	213.4	4717.3

TABLE 42. (Continued).

CIRCUMFERENCE AND AREAS OF CIRCLES.

Dia.	Cir.	Area.	Dia.	Cir.	Area.	Dia.	Cir.	Area.
78	245.0	4778.3	85 ½	268.6	5741.4	93	292.1	6792.9
½	246.6	4839.8	86	270.1	5808.8	½	293.7	6866.1
79	248.1	4901.6	½	271.7	5876.5	94	295.3	6936.7
½	249.7	4963.9	87	273.3	5944.6	½	296.8	7013.8
80	251.3	5026.5	½	274.8	6013.2	95	298.4	7088.2
½	252.8	5089.5	88	276.4	6082.1	½	300.0	7163.0
81	254.4	5153.0	½	278.0	6151.4	96	301.5	7238.2
½	256.0	5216.8	89	279.6	6221.1	½	303.1	7313.8
82	257.6	5281.0	½	281.1	6291.2	97	304.7	7389.8
½	259.1	5345.6	90	282.2	6361.7	½	306.3	7446.2
83	260.7	5410.6	½	284.3	6432.6	98	307.8	7542.9
½	262.3	5476.0	91	285.8	6503.8	½	309.4	7620.1
84	263.8	5541.7	½	287.4	6575.5	99	311.0	7697.7
½	265.4	5607.9	92	289.0	6647.6	½	312.5	7775.6
85	267.0	5674.5	½	290.5	6720.0	100	314.1	7853.9

TABLE 43.

SCOUR OF WATER-COURSE BEDS.

¼	Foot per	Second	will Scour	fine clay.
½	"	"	"	fine sand.
¾	"	"	"	coarse sand.
1	"	"	"	fine gravel.
2	"	"	"	round shingle one inch diameter.
3	"	"	"	angular stones as large as a hen's egg.
5	"	"	"	Conglomerate.

TABLE 44.

NATURAL SLOPES OF VARIOUS SUBSTANCES, WITH HORIZONTAL LINE.

Compact Earth, average,	50°	Vegetable Earth	28°
Clay, well drained	45°	Sand	22°
Rubble	45°	Wheat Flour	44°
Gravel	40°	Wheat Corn	37°
Dry Sand	38°	Peas	35°

TABLE 45.

ANIMAL POWER—WORKING EIGHT HOURS PER DAY—POUNDS RAISED ONE FOOT PER MINUTE.

Horse	21,000	Man, as in rowing	4,000
Mule	18,000	Man on treadwheel	3,100
Ox	12,000	Man turning a handle	2,600
Ass	3,500		

TABLE 46.

ROADS—THE LOAD WHICH A HORSE CAN DRAW UP DIFFERENT INCLINES ON COMMON ROADS, CALLIOG THE LOAD HE CAN DRAW ON A LEVEL 100.

On a level, can draw	100	On a rise of 1 in 30 can draw.	64
On a rise of 1 in 100 can draw.	88	" " 1 in 25 "	59
" " 1 in 75 "	84	" " 1 in 20 "	51
" " 1 in 50 "	78	" " 1 in 15 "	40
" " 1 in 40 "	72	" " 1 in 10 "	24

TABLE 47.

MEASURES OF ROCK EARTH, ETC.

25 Cubic feet of sand	= 1 ton.
18 Cubic feet of earth	= 1 ton.
17 Cubic feet of clay	= 1 ton.
13 Cubic feet of quartz, unbroken in load	= 1 ton.
18 Cubic feet of earth or gravel, unbroken	= 1 ton.
27 Cubic feet of gravel or earth, when dry	= 1 ton.
20 Cubic feet of quartz, broken (of ordinary firmness coming from the load) contract measure	= 1 ton.

WORKSHOP RECIPES.

Cement for Cast-Iron.

Two ounces of sal-amonia, one ounce of sulpher, and sixteen ounces of borings or filings of cast-iron are to be well mixed in a mortar and kept dry. One part of this powder, and twenty parts of clean iron borings or filings mixed with water into a stiff paste in a mortar render the cement ready for use. A little find grindstone sand improves the cement.

Red Lead Cement for Face Joints.

Equal parts of white lead and red lead mixed with linseed oil to the consistency of paste.

Brazing.

The edges are to be filed or scraped clean and bright, covered with spelter and powdered borax, and exposed in a clean fire to a heat sufficient to melt the solder.

Solders.

For Lead.—One part of tin and one and one half parts of lead.

For Tin.—One part of tin and two parts of lead.

For Pewter.—Two parts of tin and one part of lead.

For Hardest Brazing.—Three parts of copper and one part of zinc.

For Hard Brazing.—One part of copper and one part of zinc.

For Soft Brazing.—One part of tin, four parts of copper and three parts of zinc; or, two parts of tin and one part of antimony.

Fluxes for Soldering or Welding.

For Iron or Steel.—Borax or sal-ammoniac.

For Tinned Iron.—Resin or chloride of zinc.

For Copper or Brass.—Sal-ammoniac or chloride of zinc.

For Zinc.—Chloride of zinc.

For Lead.—Tallow or resin.

For Lead and Tin Pipes.—Resin and sweet oil.

Case Hardening With Prussiate of Potash.

Heat the articles after polishing to a bright red, rub the surface over with the prussiate of potash, allow it to cool to dull red, and immerse it in water.

Case Hardening Mixtures.

Three parts of the prussiate of potash to one part of sal-ammoniac mixed; or, two parts of sal-ammoniac, two parts of bone dust and one part of the prussiate of potash.

Mixture for Welding Steel.

One part of sal-ammoniac and ten parts of borax, powdered together and fused until clear, when it is poured out, and when cool, reduced to powder.

RECIPROCATING PUMPS.

TABLE 48.

QUANTITY OF WATER DISCHARGED BY A SINGLE STROKE.

P. M. Randall.

Dia. Inches.	One Foot Stroke. Gallons.	Dia. Inches.	One Foot Stroke. Gallons.	Dia. Inches.	One Foot Stroke. Gallons.
1.5	.0863	5.5	1.160	13.	6.481
2.	.1534	6.	1.380	14.	7.569
2.5	.2382	7.	1.879	15.	8.629
3.	.3452	8.	2.455	16.	9.818
3.5	.4698	9.	3.106	18.	12.426
4.	.6136	10.	3.835	20.	15.341
4.5	.6922	11.	4.640	22.	18.562
5.	.9588	12.	5.523	24.	22.091

In computing Table 48, the discharge is taken at 94 per cent. of the theoretical capacity of the pump, which is the average found by numerous experiments. The average efficiency of pumps as determined by many experiments is 62 per cent.

Question. A pump 12 inches in diameter, three feet stroke, makes 10 strokes per minute. Required the discharge per minute?

Answer. In Table 48, find diameter 12 inches, opposite which find 5.523 gallons for one foot stroke. Then 5.523 × 3 × 10 = 165.69 gallons per minute.

NOTICE.

The undersigned would respectfully state that he is prepared to visit, survey, examine and report on mines with a view to their character, probable value, and the best method for their development and the working of their ores; and, to superintend the construction of Quartz Mills and Mining Machinery; also, to survey mineral lands, and in general, to do hydraulic and civil engineering.

P. M. RANDALL, C. E.
U. S. Surveyor of Mineral Lands.

SAN FRANCISCO, March 28th, 1881.

Office at Golden State & Miners' Iron Works.